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Formulation and Physicochemical Evaluation of *Crescentia cujete* L. Fruit Extract Cream as A Natural Photoprotective Agent Against Ultraviolet Radiation

Rahma Diyan Martha[1]*, Armita Regina Putri Yulindasari[1], Dara Pranidya Tilarso[1], Danar Danar[2]
[1]Department of Pharmacy, STIKES Karya Putra Bangsa
Jl. Raya Tulungagung - Blitar KM.04, Sumbergempol, Tulungagung, Jawa Timur 66291, Tel. +62-0355-331080, Indonesia.
[2]Chemistry Department, Faculty of Mathematics and Natural Science, Universitas Negeri Malang
Jl. Semarang No. 5, Malang 65145, Tel. +62-341-330-1130, Fax. +62-341-551921, Indonesia.

Corresponding author*
rahmadiyan@stikes-kartrasa.ac.id

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Abstract

Ultraviolet (UV) radiation is a major environmental factor contributing to skin damage through the excessive generation of reactive oxygen species (ROS), resulting in oxidative stress, premature skin aging, hyperpigmentation, and an increased risk of skin cancer. Consequently, the development of safe and effective sunscreen formulations derived from natural products has become an important focus in cosmetic and pharmaceutical research. *Crescentia cujete L*. fruit is known to contain several bioactive secondary metabolites, including flavonoids, alkaloids, tannins, and saponins, which possess antioxidant and potential photoprotective properties. This study aimed to formulate an oil-in-water (O/W) cream containing ethanolic extract of *Crescentia cujete L.* fruit and to evaluate its physicochemical characteristics and in vitro sun protection factor (SPF). The fruit extract was obtained by maceration using 96% ethanol and incorporated into cream formulations at concentrations of 1%, 3%, and 5% (w/w). The formulations were evaluated for organoleptic properties, homogeneity, pH, viscosity, spreadability, adhesiveness, emulsion type, physical stability, skin irritation, and SPF using UV–Visible spectrophotometry over the wavelength range of 290–320 nm. The results demonstrated that increasing the extract concentration significantly enhanced the SPF values of the formulations. Among the tested formulations, the cream containing 5% extract exhibited the most favorable physicochemical properties, with a pH of 5.73 ± 0.05, viscosity of 4544 ± 4.5 cP, adhesiveness of 7.48 ± 0.08 s, spreadability of 7.40 ± 0.30 cm, and an SPF value of 5.99, corresponding to moderate photoprotection. Furthermore, the optimized formulation remained physically stable during the cycling stability test and produced no signs of skin irritation in human volunteers. These findings demonstrate that *Crescentia cujete L.* fruit extract is a promising natural photoprotective ingredient for topical sunscreen formulations and has considerable potential for further development as a plant-based sunscreen product.

Keywords: *Crescentia cujete* L.; natural sunscreen; photoprotection; physicochemical evaluation; Sun Protection Factor (SPF); UV–Visible spectrophotometry.

INTRODUCTION

Ultraviolet (UV) radiation is one of the primary environmental factors responsible for a wide range of skin disorders, including erythema, hyperpigmentation, premature skin aging, and skin cancer. Among the different UV wavelengths, UV-A and UV-B are particularly harmful because they stimulate the excessive production of reactive oxygen species (ROS), leading to oxidative stress and subsequent damage to cellular lipids, proteins, collagen, and DNA within the skin (Adaninggar et al., 2025; Purwaningsih et al., 2020). Furthermore, increasing UV exposure associated with climate change and the growing prevalence of outdoor activities has intensified the demand for effective, safe, and environmentally sustainable photoprotective products (Mmbando & Ngongolo, 2024).

Commercial sunscreen formulations predominantly rely on synthetic UV filters, such as oxybenzone and avobenzone, because of their ability to absorb ultraviolet radiation efficiently. Despite their proven efficacy, prolonged use of these compounds has raised concerns regarding potential adverse effects, including skin irritation, allergic reactions, and endocrine-disrupting activity (Amini et al., 2020; Breakell et al., 2024; Krause et al., 2012; Peranić et al., 2025). In addition to concerns about human health, the environmental persistence of certain synthetic UV filters has prompted increasing interest in identifying safer and more sustainable alternatives. Consequently, plant-derived photoprotective agents have emerged as promising candidates for the development of next-generation sunscreen formulations.

Natural products are rich sources of bioactive phytochemicals capable of protecting the skin against

UV-induced damage through multiple complementary mechanisms. Polyphenols, flavonoids, and other phenolic compounds not only absorb ultraviolet radiation through their chromophoric structures but also scavenge reactive oxygen species generated during UV exposure, thereby reducing oxidative stress and minimizing cellular damage (Avianka, 2022; Martins & Ferreira, 2022; Nichols & Katiyar, 2010; Sivamani et al., 2024). Owing to these combined antioxidant and photoprotective properties, plant-derived metabolites have attracted considerable attention as active ingredients in cosmetic and dermatological formulations.

Among the medicinal plants with potential applications in natural sunscreen development, *Crescentia cujete L.* has attracted increasing research interest because of its diverse phytochemical composition and biological activities. The fruit contains several secondary metabolites, including flavonoids, tannins, alkaloids, and saponins, which have been reported to exhibit strong antioxidant activity. Flavonoids, in particular, possess conjugated chromophore systems that enable the absorption of ultraviolet radiation while simultaneously inhibiting the formation of free radicals induced by UV exposure, thereby enhancing photoprotective (Beladini et al., 2021; Sari et al., 2022; Silalahi, 2022). Moreover, the abundant availability of *Crescentia cujete L.* in Indonesia provides an additional advantage for its sustainable utilization as a renewable source of bioactive ingredients for cosmetic and pharmaceutical applications (Azri et al., 2025; Sihotang, 2024).

Although previous studies have demonstrated the phytochemical composition and antioxidant potential of *Crescentia cujete L.*, information regarding its incorporation into topical sunscreen formulations and the comprehensive evaluation of its physicochemical properties, photoprotective efficacy, physical stability, and skin safety remains limited. Therefore, the development of a stable topical formulation capable of delivering these bioactive compounds while maintaining acceptable physicochemical characteristics represents an important research objective.

Accordingly, the present study aimed to formulate an oil-in-water (O/W) cream containing ethanolic fruit extract of *Crescentia cujete* L. at concentrations of 1%, 3%, and 5% (w/w). The resulting formulations were systematically evaluated for their organoleptic characteristics, homogeneity, pH, viscosity, spreadability, adhesiveness, emulsion type, physical stability, skin irritation potential, and in vitro Sun Protection Factor (SPF) using UV–Visible spectrophotometry. The findings are expected to contribute to the development of a safe, stable, and effective plant-based sunscreen formulation for topical photoprotection.

MATERIALS AND METHODS

Study Design

This laboratory-based experimental study was conducted at the Pharmaceutical Laboratory of STIKes Karya Putra Bangsa, Tulungagung, Indonesia. Fresh fruits of *C. cujete L.* (Figure 1) were collected from Jabalsari Village, Sumbergempol District, Tulungagung Regency, East Java, Indonesia. Prior to experimentation, the plant material was authenticated to confirm the taxonomic identity of the species in accordance with the Indonesian Herbal Pharmacopoeia guidelines (Kemenkes RI, 2022).



Figure 1. *Crescentia cujete* L. fruit.

Procedures

Chemicals and Materials

The materials used in this study included fresh fruits of *C. cujete L.*, 96% ethanol, Tween 80, Span 80, stearic acid, glycerin, liquid paraffin, methyl paraben (Nipagin), propyl paraben (Nipasol), distilled water, buffer solutions, and reagents required for phytochemical screening. All formulation ingredients were of pharmaceutical grade and complied with analytical quality standards (Rowe et al., 2009; Yuni et al., 2023). The cream formulation was prepared with slight modifications to the sunscreen formulation previously reported by Yuni et al. (2023).

Preparation of Crescentia cujete L. Fruit Extract

Fresh fruits of *C. cujete L.* were washed thoroughly, cut into small pieces, and dried to obtain dried simplicia. The dried material was pulverized into a fine powder prior to extraction. The powdered simplicia were extracted by maceration using 96% ethanol as the extraction solvent. During the maceration process, the mixture was stirred periodically to facilitate solvent penetration and improve

extraction efficiency. The resulting filtrate was concentrated under reduced pressure using a rotary evaporator to obtain a viscous ethanolic extract. Maceration was selected because it effectively preserves thermolabile secondary metabolites by avoiding exposure to elevated temperatures during extraction (Ningsih & Atiqah, 2020).

Phytochemical Screening

Qualitative phytochemical screening of the ethanolic fruit extract was performed to identify the presence of flavonoids, alkaloids, tannins, and saponins using standard qualitative reagent-based methods. The screening results were used to verify the presence of bioactive secondary metabolites that may contribute to the antioxidant and photoprotective properties of the extract (Basuki, 2017).

Cream Formulation

The cream formulations were prepared using three different concentrations of *Crescentia cujete L.* fruit extract, namely 1% (F1), 3% (F2), and 5% (F3, w/w), while the cream base without extract (F0) served as the control formulation. An oil-in-water (O/W) emulsion system was prepared using Tween 80 and Span 80 as emulsifying agents. The oil and aqueous phases were heated separately to the same temperature before being combined under continuous stirring until a homogeneous cream base was obtained. After cooling to an appropriate temperature, the fruit extract was gradually incorporated into the cream base with continuous mixing until a uniform formulation was produced (Yuni et al., 2023).

Evaluation of Physicochemical Properties

The prepared cream formulations were evaluated for their physicochemical characteristics, including organoleptic properties, homogeneity, emulsion type, pH, viscosity, spreadability, adhesiveness, physical stability, and skin irritation potential. Organoleptic evaluation included observations of color, odor, appearance, and consistency. Homogeneity was assessed by visual examination to ensure uniform distribution of the extract throughout the cream matrix. The emulsion type was determined using standard identification methods.

The pH of each formulation was measured using a calibrated digital pH meter, whereas viscosity was determined using a viscometer. Spreadability and adhesiveness were evaluated using standard analytical procedures to assess the ease of application and the ability of the formulation to remain in contact with the skin surface. Physical stability was assessed using the cycling test, which involved alternating storage under low- and high-temperature conditions for several cycles to evaluate possible physical changes in the cream formulation (Amini et al., 2020).

In Vitro Determination of Sun Protection Factor (SPF)

The Sun Protection Factor (SPF) of each formulation was determined in vitro using UV–Visible spectrophotometry over the wavelength range of 290–320 nm. Cream samples were dissolved in an appropriate solvent, and the absorbance was measured at predetermined wavelength intervals. SPF values were subsequently calculated using the Mansur equation to evaluate the photoprotective efficacy of each formulation (Pratama & Zulkarnain, 2015).

Statistical Analysis

All experiments were performed in triplicate, and the results are presented as mean ± standard deviation (SD). Statistical differences among formulations were analyzed using one-way analysis of variance (one-way ANOVA) to determine the effect of extract concentration on the physicochemical properties and SPF values of the cream formulations.

RESULTS AND DISCUSSION

Phytochemical Screening

Qualitative phytochemical screening demonstrated that the ethanolic extract of *Crescentia cujete L*. fruit contained flavonoids, alkaloids, tannins, and saponins (Table 1). The detection of these secondary metabolites indicates that the extract possesses bioactive constituents potentially associated with antioxidant and photoprotective activities (Basuki, 2017; Silalahi, 2022; Yahya et al., 2025).

Table 1. Qualitative phytochemical screening of the ethanolic extract of *Crescentia cujete L.* fruit.

Phytochemical	Reagent	Result
Alkaloids	HCl	+
Flavonoids	NaOH	+
Saponins	Distilled water	+
Tannins	$FeCl_3$	+

Characteristics of *Crescentia cujete L.* Fruit Extract Cream

Cream formulations containing *Crescentia cujete L.* fruit extract were successfully prepared at extract concentrations of 1% (F1), 3% (F2), and 5% (F3), with the extract-free cream base (F0) serving as the control. All formulations produced homogeneous semi-solid creams with a characteristic odor of the fruit extract. The color of the formulations became progressively darker with increasing extract concentration, whereas no phase separation or visible coarse particles were observed throughout the preparation process (Amini et al., 2020). Homogeneity testing confirmed the uniform distribution of the extract within the cream matrix for all formulations, indicating successful incorporation of the

active ingredients into the emulsion system (Purwaningsih et al., 2020).

Physicochemical Evaluation

The physicochemical properties of the cream formulations are summarized in Table 2. All formulations fulfilled the general quality requirements for topical cream preparations, although variations in extract concentration influenced several physicochemical parameters. The pH values of all formulations ranged from 5.50 ± 0.17 to 5.73 ± 0.05, remaining within the physiological pH range of human skin (4.5–6.5), thereby indicating their suitability for topical application (Kim et al., 2024). The highest pH value was observed for formulation F3.

Viscosity increased progressively with increasing extract concentration. Formulation F3 exhibited the highest viscosity (4544 ± 4.5 cP), suggesting that increasing amounts of plant extract enhanced the consistency of the cream matrix, a trend consistent with previous reports on semisolid topical formulations (Wulanawati et al., 2019). Formulation F3 exhibited the highest viscosity (4544 ± 4.5 cP), whereas the control formulation (F0) showed the lowest viscosity (2869 ± 4 cP). A slight reduction in spreadability accompanied the increase in viscosity; however, all formulations remained within the acceptable range for topical application (Purwaningsih et al., 2020). Formulation F3 demonstrated a spreadability of 7.40 ± 0.30 cm. Conversely, adhesiveness increased with increasing extract concentration, indicating improved retention of the cream on the skin surface (Purwaningsih et al., 2020). The highest adhesiveness was observed in formulation F3, with a value of 7.48 ± 0.08 s. All formulations exhibited an oil-in-water (O/W) emulsion type throughout the evaluation period.

Table 2. Physicochemical properties and SPF values of Crescentia cujete L. fruit extract cream formulations.

Formulation	Homogeneity	pH	Viskosity (cP)	Adhesiveness (s)	Speadability (cm)	SPF
F0	Homogenous	5.50 ± 0.17	2869 ± 4.0	7.30 ± 0.07	7.8 ± 0.17	2.14
F1	Homogenous	5.70 ± 0.10	3004 ± 4.0	7.39 ± 0.06	7.6 ± 0.17	5.15
F2	Homogenous	5.67 ± 0.06	3932 ± 4.5	7.34 ± 0.08	7.5 ± 0.26	5.35
F3	Homogenous	5.73 ± 0.05	4544 ± 4.5	7.48 ± 0.08	7.4 ± 0.30	5.99

In Vitro Sun Protection Factor (SPF)

The in vitro SPF values increased progressively with increasing concentrations of Crescentia cujete L. fruit extract (Figure 2), indicating enhanced photoprotective efficacy. This trend is consistent with the increasing abundance of flavonoids, tannins, and other phenolic compounds, which possess UV-absorbing chromophores and antioxidant propertie (Nichols & Katiyar, 2010; Silalahi, 2022). The control formulation (F0) exhibited an SPF value of 2.14, whereas formulations containing 1%, 3%, and 5% extract produced SPF values of 5.15, 5.35, and 5.99, respectively. Based on the adopted classification system, formulations F1–F3 provided moderate photoprotective activity, with formulation F3 exhibiting the highest SPF value among all tested formulations. Considering both the physicochemical characteristics and photoprotective performance, formulation F3 was selected as the optimum formulation for subsequent stability and skin irritation studies.

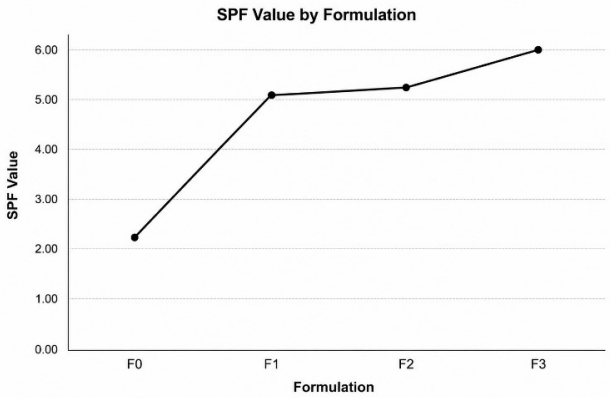


Figure 2. SPF Test Values

Physical Stability (Cycling Test)

The physical stability of the optimum formulation (F3) was evaluated using the cycling test. No visible changes in color, odor, consistency, or homogeneity were observed after six storage cycles, indicating satisfactory physical stability of the emulsion system (Rowe et al, 2023). A slight reduction in pH was observed during storage, decreasing from 5.73 ± 0.05 to approximately 5.30. Despite this decrease, the pH remained within the acceptable physiological range for topical application (Kim et al., 2024).

Spreadability showed a gradual decline during the cycling test, from 7.40 cm to approximately 6.00 cm at the final cycle (Wulanawati et al., 2019). Conversely, adhesiveness increased slightly throughout storage, reaching 7.48 s at the end of the stability test

(Purwaningsih et al., 2020). Overall, formulation F3 maintained acceptable physicochemical characteristics throughout the cycling test.

Skin Irritation Test

The skin irritation test was conducted using 15 healthy volunteers to evaluate the topical safety of the optimized cream formulation. Throughout the observation period, none of the participants exhibited signs of erythema, itching, burning sensation, or edema following topical application (Kim et al., 2024).

Discussion

The present study demonstrated that the ethanolic extract of *Crescentia cujete* L. fruit can be successfully incorporated into an oil-in-water (O/W) cream formulation while maintaining acceptable physicochemical characteristics and exhibiting measurable photoprotective activity. Qualitative phytochemical screening confirmed the presence of flavonoids, tannins, alkaloids, and saponins, all of which have previously been reported as important bioactive constituents responsible for antioxidant and photoprotective activities (Basuki, 2017; Silalahi, 2022; Yahya et al., 2025). The detection of these metabolites provides a phytochemical basis for the biological performance of the formulated cream observed in the present study.

Among the identified compounds, flavonoids are considered the principal contributors to photoprotection because of their conjugated aromatic structures, which function as chromophores capable of absorbing ultraviolet radiation. In addition to direct UV absorption, flavonoids and other phenolic compounds scavenge reactive oxygen species (ROS) generated during UV exposure, thereby reducing oxidative damage to cellular lipids, proteins, and DNA (Nichols & Katiyar, 2010; Silalahi, 2022). Consequently, the photoprotective efficacy of *Crescentia cujete* L. fruit extract is likely attributable to the combined UV-filtering and antioxidant properties of these phytochemicals.

All cream formulations exhibited satisfactory physicochemical characteristics, including homogeneity, appropriate pH, acceptable viscosity, spreadability, adhesiveness, and a stable oil-in-water emulsion system. These findings indicate that incorporation of the ethanolic fruit extract did not adversely affect the overall quality of the topical formulation. The pH values of all formulations remained within the physiological pH range of human skin (4.5–6.5), suggesting that the creams are suitable for topical application and are unlikely to disrupt the natural skin barrier (Kim et al., 2024). Likewise, the observed increase in viscosity with increasing extract concentration is consistent with the incorporation of additional solid constituents into the cream matrix, resulting in a more structured semisolid system (Wulanawati et al., 2019).

As expected, the increase in viscosity was accompanied by a slight reduction in spreadability. Nevertheless, all formulations remained within the acceptable range for topical application, indicating that the creams retained satisfactory application properties. At the same time, adhesiveness increased with increasing extract concentration, suggesting prolonged contact between the formulation and the skin surface, which may enhance the retention of bioactive compounds and potentially improve photoprotective performance (Purwaningsih et al., 2020). The O/W emulsion type observed in all formulations is also advantageous for sunscreen products because it facilitates easy application, rapid spreading, and convenient removal with water, thereby improving user acceptability (Purwaningsih et al., 2020).

One of the principal findings of this study was the progressive increase in SPF values with increasing concentrations of Crescentia cujete L. fruit extract. The control formulation exhibited only minimal photoprotective activity (SPF 2.14), whereas formulations containing 1%, 3%, and 5% extract demonstrated SPF values of 5.15, 5.35, and 5.99, respectively, corresponding to moderate photoprotection. This concentration-dependent increase strongly suggests that the photoprotective efficacy of the cream is associated with the increasing abundance of flavonoids, tannins, and other phenolic compounds in the extract. These phytochemicals possess conjugated chromophore systems capable of absorbing ultraviolet radiation while simultaneously suppressing oxidative stress through antioxidant mechanisms (Nichols & Katiyar, 2010; Silalahi, 2022). The dual functionality of UV absorption and free-radical scavenging provides a plausible explanation for the enhanced SPF observed in formulations containing higher extract concentrations.

Based on the combined evaluation of physicochemical properties and SPF values, formulation F3 was selected as the optimum formulation. In addition to exhibiting the highest SPF value, F3 maintained acceptable physicochemical characteristics throughout the study and demonstrated satisfactory physical stability during the cycling test. No significant changes were observed in color, odor, consistency, or homogeneity after repeated exposure to alternating storage temperatures, indicating that the emulsion system remained stable. Although slight changes in pH, spreadability, and adhesiveness occurred during storage, all measured values remained within acceptable limits for topical formulations. The observed stability may be attributed to the effective emulsification provided by the combination of Tween 80 and Span 80, which has previously been reported to enhance emulsion stability in semisolid pharmaceutical formulations (Amini et al., 2020;Rowe et al, 2023).

The safety evaluation further demonstrated that the optimized cream formulation did not induce erythema, itching, burning sensation, or edema in any of the 15

volunteers included in the skin irritation study. The absence of visible irritation suggests that the formulation is well tolerated under the experimental conditions employed. This favorable safety profile may be associated with both the skin-compatible pH of the formulation and the antioxidant and anti-inflammatory activities of flavonoids, which have been reported to mitigate inflammatory responses induced by oxidative stress (Kim et al., 2024).

Although the present study demonstrates the potential of Crescentia cujete L. fruit extract as a natural photoprotective ingredient, several limitations should be acknowledged. The SPF evaluation was conducted exclusively under in vitro conditions, and therefore the results may not fully represent in vivo photoprotective performance. Furthermore, the phytochemical composition of the extract was assessed qualitatively rather than quantitatively, preventing direct correlation between individual bioactive compounds and SPF values. Future studies should focus on quantitative phytochemical analysis, long-term stability evaluation, in vivo photoprotection studies, and identification of the specific constituents responsible for UV protection. Such investigations would provide a more comprehensive understanding of the formulation and support its further development as a plant-based sunscreen product.

Overall, the findings of this study demonstrate that *Crescentia cujete* L. fruit extract possesses promising potential as a natural active ingredient for topical sunscreen formulations. The optimized cream exhibited favorable physicochemical characteristics, moderate photoprotective activity, acceptable physical stability, and satisfactory skin compatibility, supporting its potential application in the development of safer and more sustainable cosmetic products.s (Nichols & Katiyar, 2010; Silalahi, 2022).

CONCLUSIONS

The present study successfully developed an oil-in-water (O/W) cream containing ethanolic extract of *Crescentia cujete* L. fruit and demonstrated its potential as a natural photoprotective formulation. Incorporation of the fruit extract into the cream base produced stable and homogeneous formulations with physicochemical characteristics that were suitable for topical application.

Among the tested formulations, the cream containing 5% (w/w) *Crescentia cujete* L. fruit extract exhibited the most favorable overall performance, combining acceptable pH, viscosity, spreadability, adhesiveness, physical stability, and the highest in vitro Sun Protection Factor (SPF). Furthermore, the optimized formulation remained stable during the cycling stability test and produced no observable skin irritation under the experimental conditions employed.

The observed photoprotective activity is likely associated with the presence of flavonoids, tannins, and other phenolic constituents identified in the extract, which contribute to ultraviolet absorption and antioxidant activity. These findings demonstrate that *Crescentia cujete* L. fruit extract represents a promising natural source of photoprotective compounds for topical sunscreen formulations. Further investigations involving quantitative phytochemical analysis, long-term stability studies, and in vivo photoprotection assessments are recommended to confirm the efficacy and safety of the formulation and to support its future development as a plant-based sunscreen product.

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