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Research Article

In Vitro Sunscreen Activity of Purple Passion Fruit (*Passiflora edulis*) Peel Extract

Aktivitas Tabir Surya secara In Vitro dari Ekstrak Kulit Markisa (Passiflora edulis)

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ABSTRACT

Excessive exposure to Ultraviolet (UV) radiation can cause skin damage, including erythema, premature ageing, and skin cancer. Sunscreen is commonly used to protect the skin from UV radiation. The peel of purple passion fruit (*Passiflora edulis*) contains phenolic and flavonoid compounds that may provide UV-absorbing activity. This study aimed to evaluate the sunscreen activity of the ethanol extract of purple passion fruit peel in vitro based on the Sun Protection Factor (SPF), Erythema Transmission Percentage (%Te), and Pigmentation Transmission Percentage (%Tp). The extract was obtained by maceration with 96% ethanol. Qualitative identification of phenolic compounds was performed using a $FeCl_3$ reagent, while flavonoids were detected using concentrated HCl and magnesium powder. Sunscreen activity was evaluated using UV-Vis spectrophotometry at concentrations of 400, 600, 800, 1,000, and 1,200 ppm. The results showed that the extract contained phenolic and flavonoid compounds. At the highest concentration (1,200 ppm), the SPF value was 20.086±1.696 (ultra-protection), %Te was 0.697±0.149, and %Tp was 4.413±0.594, all of which were categorised as sunscreen. One-way ANOVA analysis indicated significant differences among concentration variations ($p<0.05$). In conclusion, the ethanol extract of purple passion fruit peel has potential as a natural active ingredient for sunscreen.

Keywords: Purple Passion Fruit; Sunscreen; SPF; %Te; %Tp

ABSTRAK

Paparan sinar Ultraviolet (UV) berlebih dapat menyebabkan kerusakan kulit, seperti eritema, penuaan dini, hingga kanker kulit. Salah satu upaya proteksi terhadap radiasi UV dengan penggunaan tabir surya. Kulit buah markisa ungu (Passiflora edulis) diketahui memiliki kemampuan menyerap sinar UV karena mengandung senyawa fenolik dan flavonoid. Penelitian ini bertujuan untuk mengevaluasi aktivitas tabir surya dari ekstrak etanol kulit markisa ungu secara in vitro, berdasarkan nilai Sun Protection Factor (SPF), Persentase Transmisi Eritema (%Te), dan Persentase Transmisi Pigmentasi (%Tp) menggunakan metode spektrofotometri UV-Vis. Ekstrak diperoleh melalui metode maserasi dengan pelarut etanol 96%. Uji kualitatif senyawa fenolik menggunakan

pereaksi $FeCl_3$, sementara flavonoid menggunakan pereaksi HCl pekat dan bubuk magnesium. Uji aktivitas tabir surya dengan metode spektrofotometri UV-Vis terhadap lima variasi konsentrasi (400, 600, 800, 1.000 dan 1.200 ppm). Hasil menunjukkan bahwa ekstrak kulit markisa ungu memiliki kandungan flavonoid dan fenolik. Pada konsentrasi tertinggi 1.200 ppm, nilai SPF sebesar 20,086±1,696 (proteksi ultra), %Te sebesar 0,697±0,149, dan %Tp sebesar 4,413±0,594, keduanya dikategorikan sebagai tabir surya. Hasil analisis One-Way ANOVA menunjukkan perbedaan signifikan antar variasi konsentrasi (p<0,05). Kesimpulannya, ekstrak etanol kulit markisa ungu memiliki potensi sebagai bahan aktif tabir surya alami.

Kata Kunci: *Kulit Markisa Ungu; Tabir Surya; SPF; %Te; %Tp*

INTRODUCTION

Ultraviolet (UV) radiation is an unavoidable component of sunlight that significantly impacts human skin health. Although UVC radiation does not reach the Earth's surface, as it is filtered by the atmosphere, both UVA (320–400 nm) and UVB (290–320 nm) rays can still cause various skin problems. These include erythema, premature ageing (photoageing), hyperpigmentation, DNA damage, impaired immune function, and even skin cancer. The World Health Organization (WHO) also notes that the incidence of skin damage caused by UVA and UVB exposure continues to rise due to climate change and the thinning of the ozone layer, making the need for effective skin protection increasingly urgent (1).

Sunscreen is one of the most commonly used forms of protection, as its compounds can reduce the harmful effects of UV radiation by effectively absorbing it at specific wavelengths (2). However, numerous studies indicate that many commercial sunscreens still contain chemicals such as oxybenzone, octinoxate, avobenzone, and homosalate. These ingredients have the potential to cause skin irritation, trigger allergic reactions, act as endocrine disruptors, and pollute aquatic environments (3,4). Furthermore, some sunscreens offer unbalanced protection against UVA and UVB rays, leading to reduced effectiveness (5). These limitations in current synthetic sunscreen formulations highlight the need for an alternative approach: sourcing natural active ingredients that are safer, more effective, and environmentally friendly (6).

The peel of *Passiflora edulis* is known to contain bioactive compounds such as flavonoids and phenolics. Purple passion fruit rind contains important secondary metabolites such as gallic acid, chlorogenic acid, piceatannol, vitexin, quercetin, luteolin, and myricetin (3). These compounds possess antioxidant and anti-inflammatory activities, enabling them to neutralise free radicals, inhibit collagen and elastin-degrading enzymes, and protect the skin from UV-induced damage. The combination of these mechanisms supports the potential of passion fruit rind extract as an anti-ageing active ingredient. These compounds possess chromophore groups that absorb UV radiation, making them potential active ingredients in sunscreen formulations (4). Flavonoids are also recognised as strong antioxidants that can protect the skin from free radicals generated by UV exposure (5). This study aims to evaluate the sunscreen activity of the ethanol extract of purple passion fruit peel based on Sun Protection Factor (SPF), Erythema Transmission Percentage (%Te), and Pigmentation Transmission Percentage (%Tp) values in vitro using the UV-Vis spectrophotometric method. The selection of these parameters is based on their biological relevance: SPF measures protection against UVB, the primary cause of erythema; %Te assesses erythema risk by measuring UVB transmission through the formulation; and %Tp serves as a proxy for UVA exposure, which can induce skin pigmentation. The combination of these three indicators enables a comprehensive evaluation of sunscreen effectiveness from various aspects of skin protection.

This study differs from previous work in its sample collection site and the set of testing parameters employed. Whereas the earlier study was limited to evaluating the sunscreen potential of purple passion fruit rind ethanol extract based solely on the SPF and %Te, with results of SPF 16.28 and %Te 3.98%

indicating ultra-level protection, the present research expands the assessment to include not only SPF and %Te but also the %Tp (6). By measuring %Tp, this study demonstrates that the extract protects against both UVB (which causes sunburn) and UVA radiation. This is crucial, since UVA not only darkens the skin but also causes premature ageing, such as wrinkles, and increases the risk of skin cancer.

MATERIALS AND METHODS

Materials

The purple passion fruit simplicia was obtained from Randurejo Village, Boyolali, Central Java, with the determination certificate number 446/Lab.Bio/B/VII/2025, issued by the Biology Laboratory, Faculty of Applied Science and Technology, Ahmad Dahlan University. The materials used were purple passion fruit peel, Magnesium powder (Mg, Merck), concentrated Hydrochloric Acid (HCl, Merck), 1% Ferric Chloride ($FeCl_3$, Merck), 96% ethanol (Medika), analytical-grade ethanol (Medika), and distilled water (Merck).

Methods

This study was experimental and conducted at the Pharmaceutical Biology Laboratory, Sahid University, Surakarta. The population in this study comprised purple passion fruit from the Boyolali region. The sample employed in this research was the ethanol extract of purple passion fruit peel. The ethanol extract of purple passion fruit peel was analysed for extraction yield, moisture content (in triplicate; Replication 1–3), organoleptic properties, and qualitative phytochemical screening to detect the presence of phenolic and flavonoid compounds. The independent variables included concentrations of the ethanol extract of purple passion fruit peel at 400, 600, 800, 1,000, and 1,200 ppm. Concentrations of 400, 600, 800, 1,000, and 1,200 ppm were tested to demonstrate a dose-dependent effect. The results clearly showed that higher concentrations provided better sun protection, with 1,200 ppm offering the strongest SPF. The dependent variables in this study were the determination of the SPF and the %Te and %Tp values of the ethanol extract of purple passion fruit peel.

Extraction of Purple Passion Fruit Peel Samples

The extraction method used in this research was maceration. The maceration method was chosen due to its simplicity, ease of execution, and because it does not involve a heating process, thereby reducing the risk of damaging the chemical compounds present in the sample. The solvent used in this study was 96% ethanol, which functions to extract phenolic and flavonoid compounds. Ethanol was selected as the solvent because phenolic and flavonoid compounds, in both glycone and aglycone forms, are polar and require a polar solvent for optimal dissolution (6). A total of 127.36 g of finely ground purple passion fruit peel was placed into a maceration vessel, followed by the addition of 1,273.6 mL of 96% ethanol (1:10 ratio). The mixture was stored for 3 days, protected from sunlight, with occasional stirring. After this period, the mixture was filtered, and the residue was remacerated with 1,273.6 mL of 96% ethanol for 24 hours. The resulting filtrate was then re-filtered again and evaporated using a water bath until a thick extract was obtained (4).

Moisture Content Test of the Extract

A total of 0.5 g of thick ethanol extract of purple passion fruit peel was weighed and placed into a moisture analyser. The sample was then heated, and the measurement was continued until the moisture content value of the extract was displayed (7).

Identification of Phenolic Compounds

A total of 1 mL of the extract was placed into a test tube, followed by the addition of a few drops of 1% $FeCl_3$ solution. A positive reaction was indicated by the formation of a green or dark green colour (8).

Identification of Flavonoid Compounds

A total of 1 mL of the extract was placed into a test tube and heated for 15 minutes, after which a few drops of concentrated HCl and 0.5 g of Mg powder were added. A positive reaction was indicated by the appearance of a red, yellow, or orange colour (2).

Preparation of the SPF Test Solution

A total of 200 mg of purple passion fruit peel extract was dissolved in analytical-grade ethanol up to the 50 mL mark in a volumetric flask, resulting in a 4,000 ppm stock solution. The stock solution was then diluted to produce five concentrations: 400, 600, 800, 1,000, and 1,200 ppm, each replicated three times. Subsequently, the SPF, %Te, and %Tp values of the ethanol extract of purple passion fruit peel were determined (9).

Determination of the Absorption Profile

The absorption profile was determined using a UV-Vis spectrophotometer (Genesys 10S, Thermo Fisher Scientific, USA) to measure the extract's ability to absorb UV radiation in the ranges of 290–320 nm (UVB) and 320–400 nm (UVA), with analytical-grade ethanol used as the blank. The measurements were taken at 5 nm intervals for each sample concentration and were repeated three times. The average absorbance values were then plotted to obtain the absorption profile and to determine the maximum wavelength (λ_{max}). This λ_{max} value was used as a basis for assessing the extract's photoprotective potential, following modern spectrophotometry-based photoprotection analysis methods.

Determination of SPF Values

The SPF values were measured using a UV-Vis spectrophotometer on ethanol extract solutions at concentrations of 400, 600, 800, 1,000, and 1,200 ppm, over a wavelength range of 290–320 nm in 5 nm intervals, with ethanol as the blank. The absorbance was multiplied by Erythemal Effect Spectrum (EE) × Sun Intensity Spectrum (I) and a correction factor of 10 (10).

Determination of %Te and %Tp

The %Te and %Tp values were determined using a UV-Vis spectrophotometer. For %Te, the transmittance of ethanol extract solutions at concentrations of 400, 600, 800, 1,000, and 1,200 ppm was measured over 292.5–317.5 nm in 5 nm intervals, using ethanol as the blank. For %Tp, transmittance was measured at wavelengths of 322.5–372.5 nm in 5 nm intervals, using ethanol as the blank (11).

Data Analysis

Statistical analysis in this study was conducted using Statistical Package for the Social Sciences (SPSS) version 27.0. Statistical analysis was employed because the study involved more than two groups. The aspects evaluated statistically included the consistency of results across replications, the mean and Standard Deviation (SD) values to assess data stability, as well as the differences and trends in SPF, %Te, and %Tp values across various extract concentrations. The SPF, %Te, and %Tp data of the ethanol extract of purple passion fruit peel were first tested for normality using the Shapiro-Wilk test and for homogeneity of variance using Levene’s test. If the data met the assumptions of normality and homogeneity, a One-Way ANOVA was used to evaluate significant differences in the sunscreen potential produced.

RESULTS

Purple Passion Fruit Peel Extraction

This study used purple passion fruit peel, which was washed and separated from the seeds and pulp. The obtained peel was then dried in an oven at 60°C. The selection of a temperature of 60°C is an optimisation between drying speed and protection of bioactive compounds, resulting in high-quality dried simplicia for the subsequent extraction process. Once dried, the simplicia were blended, yielding a weight of 127.36 g, and subsequently extracted by maceration using 96% ethanol at a ratio of 1:10, resulting in 1,273.6 mL of 96% ethanol. Remaceration was carried out until a thick extract of 27.20 g was obtained, as shown in **Table 1**.

Table 1. Extraction Yield of *Passiflora edulis* Fruit Peel Extract

Wet Simplicia Weight (g)	Ethanol Thick Extract Weight (g)	Yield (%)
127.36	27.20	21.35

Moisture Content Test

This test was carried out using a moisture analyser by weighing 0.5 g of the thick purple passion fruit peel extract, which was then placed in the analyser at 105°C. The results are presented in **Table 2**.

Table 2. Moisture Content of *Passiflora edulis* Fruit Peel Extract

Moisture Content Test	Results
Replication 1	0.93%
Replication 2	1.99%
Replication 3	1.29%
Mean±SD	1.423±0.513

Qualitative Test

Organoleptic testing was carried out to observe the form, aroma, and colour produced by the ethanol extract of purple passion fruit peel, as shown in **Table 3**.

Table 3. Organoleptic Characteristics of *Passiflora edulis* Fruit Peel Extract

Test	Result
Form	Thick
Colour	Dark brown
Aroma	Characteristic odour of purple passion fruit peel extract

Qualitative testing of the 96% ethanol extract of purple passion fruit peel showed the presence of flavonoids and phenolic compounds, as presented in **Table 4**.

Table 4. Phytochemical Screening of Phenolic and Flavonoid Compounds in the Ethanol Extract of *Passiflora edulis* Fruit Peel

Test	Reagent	Result	Conclusion
Flavonoid	Concentrated HCl + Mg powder	Formation of yellow or orange colour	(+)
Phenolic	1% $FeCl_3$	Formation of dark greenish colour	(+)

Sunscreen Potential Value

SPF Values

The SPF values were determined from the absorbance of the ethanol extract of purple passion fruit peel using UV-Vis spectrophotometry over the wavelength range of 290–320 nm, with three replicates for each concentration. The results are presented in **Table 5**.

Table 5. Sun Protection Factor (SPF) Values of *Passiflora edulis* Fruit Peel Extract

Sample (Extract)	SPF Value				
	400 ppm	600 ppm	800 ppm	1,000 ppm	1,200 ppm
Replication 1	4.827	8.093	9.559	10.473	18.500
Replication 2	5.501	9.142	10.872	11.666	19.884
Replication 3	6.451	10.211	11.070	13.229	21.847
Mean±SD	5.593± 0.815	9.148± 1.059	10.500± 0.821	11.456± 0.896	20.086± 1.696
Category	Extra	Maximum	Maximum	Maximum	Ultra

An SPF value of 20.086±1.696 indicates that the extract provides strong protection against UVB radiation. This level of protection can reduce the risk of erythema (sunburn) by more than 95% in practical use.

Erythema Transmission (%Te)

The %Te value was measured with UV-Vis spectrophotometry over the wavelength range of 292.5–317.5 nm, with three replicates. The results are presented in **Table 6**.

Table 6. Erythema Transmission (%Te) Values of *Passiflora edulis* Fruit Peel Extract

Sample (Extract)	%Te Value				
	400 ppm	600 ppm	800 ppm	1,000 ppm	1,200 ppm
Replication 1	28.404	6.777	7.755	2.060	0.657
Replication 2	27.187	7.708	6.646	1.439	0.863
Replication 3	27.040	7.107	7.551	2.246	0.572
Mean±SD	27.543± 0.748	7.197± 0.472	7.317± 0.590	1.915± 0.422	0.697± 0.149
Category	Not classified in the category	Standard suntan	Standard suntan	Extra protection	Sunblock

A %Te value of 0.697±0.149 indicates that less than 1% of UVB radiation penetrates the formulation. This demonstrates very strong efficacy in preventing redness (erythema), comparable to a sunblock.

Pigmentation Transmission (%Tp) Values

The %Tp value was determined by UV-Vis spectrophotometry over the wavelength range of 322.5–372.5 nm, with three replicates. The results are presented in **Table 7**.

Table 7. Pigmentation Transmission (%Tp) Values of *Passiflora edulis* Fruit Peel Extract

Sample (Extract)	%Tp Value				
	400 ppm	600 ppm	800 ppm	1,000 ppm	1,200 ppm
Replication 1	30.465	23.054	18.963	8.681	5.053
Replication 2	29.372	22.122	18.074	7.484	4.308
Replication 3	29.180	21.100	17.156	6.434	3.879
Mean±SD	29.672± 0.693	22.092± 0.977	18.064± 0.903	7.533± 1.124	4.413± 0.594
Category	Sunblock	Sunblock	Sunblock	Sunblock	Sunblock

A %Tp value of 4.413±0.594 means that only approximately 4% of the skin-pigmenting UVA radiation is transmitted. This indicates a strong ability to inhibit UVA-induced skin darkening.

Statistical Analysis of Concentration Variations

Normality testing of the purple passion fruit peel ethanol extract was carried out using the Shapiro–Wilk test with three replicates at each concentration. The test results showed $p>0.05$, indicating that the samples were normally distributed. The normality results are presented in **Table 8**.

Table 8. Normality Test Results of *Passiflora edulis* Fruit Peel Extract In Vitro Sunscreen Activity

Concentration	Normality Value		
	SPF	%Te	%Tp
400 ppm	0.813	0.188	0.265
600 ppm	0.990	0.682	0.949
800 ppm	0.231	0.332	0.982
1,000 ppm	0.610	0.424	0.928
1,200 ppm	0.803	0.550	0.706

Note: p>0.05 indicates that the sample is normally distributed, whereas p<0.05 indicates that the sample is not normally distributed.

Homogeneity testing was carried out using Levene's test, where p>0.05 indicates that the data are homogeneous. The homogeneity results are presented in **Table 9**.

Table 9. Homogeneity Test Results of *Passiflora edulis* Fruit Peel Extract In Vitro Sunscreen Activity

Sunscreen Test	Homogeneity Test
SPF	0.660
%Te	0.135
%Tp	0.917

Note: p>0.05 indicates that the sample is homogeneously distributed, whereas p<0.05 indicates that the sample is not homogeneously distributed.

The One-Way ANOVA statistical test showed that the purple passion fruit peel ethanol extract obtained a value of 0.001 (p<0.05), indicating a significant difference in sunscreen effectiveness at each concentration of the purple passion fruit peel ethanol extract. The results are presented in **Table 10**.

Table 10. One-Way ANOVA Statistical Test Results of *Passiflora edulis* Fruit Peel Extract In Vitro Sunscreen Activity

Value	Significance Value
SPF	0.001
%Te	0.001
%Tp	0.001

Note: p<0.05 indicates that the sample has a significant variation in concentration comparisons, whereas p>0.05 indicates that the sample does not have a significant variation in concentration comparisons.

DISCUSSION

Sunscreen is a cosmetic preparation designed to protect the skin from UV radiation by absorbing UVB and partially reflecting UVA and UVB (16). The effectiveness of sunscreen depends on the ability of its active ingredients to absorb radiation, particularly UVB within the 290–320 nm range. A high-quality sunscreen should be capable of absorbing at least 85% of the radiation at these wavelengths (17). Purple passion fruit rind ethanol extract contains flavonoids and phenolic compounds, which function as UV absorbers due to their aromatic groups and conjugated systems that can capture photon energy (18). This mechanism allows these compounds to inhibit the penetration of UV radiation into the skin layers. Moreover, several studies suggest that the combination of flavonoids and phenolics may produce a synergistic effect, enhancing both photochemical stability and radiation protection capacity. Phenolic compounds and flavonoids contain aromatic rings in their structure that can absorb UV rays to reduce the risk of sunburn, thereby acting as a natural UV filter (6).

In this study, a yield of 21.35% was obtained. This result is consistent with previous research by Suryadi *et al*., (2021), which reported a yield of 14.5% for the ethanol extract of purple passion fruit leaves (2), and with research by Weyya *et al*., (2024), which reported a yield of 11.9% for the ethanol extract of purple passion fruit pulp (7). These values are considered acceptable because a yield exceeding 10% indicates a good extraction result. The calculation of extract yield is regarded as satisfactory when the obtained yield value exceeds 10% (8). Subsequently, moisture content testing of the ethanol extract of purple passion fruit peel was carried out using a moisture analyser. In this study, the moisture content of the ethanol extract of purple passion fruit peel was found to be 0.99% for replication 1, 1.99% for replication 2, and 1.29% for replication 3. The mean±SD value obtained was 1.423%±0.513. These results meet the required standard of <10% (9).

The phytochemical test results indicate that the ethanol extract of purple passion fruit peel contains flavonoid and phenolic compounds, as evidenced by characteristic colour changes in the respective tests. In the flavonoid test, the appearance of a colour change after the addition of

magnesium powder and concentrated HCl confirmed the presence of flavonoid compounds. A positive test for flavonoids may produce a yellow or orange colour. Meanwhile, the phenolic test using $FeCl_3$ reagent showed a colour change to a dark greenish-black, indicating the formation of a complex between Fe^{3+} ions and the aromatic hydroxyl groups of the phenolic compounds (8,9). These findings align with related research on the compound content of passion fruit. For instance, research by Susanti *et al*., (2019) on purple passion fruit peel (14), by Septinigrum *et al*., (2024) on purple passion fruit peel and leaves (19), and by Sudarwati *et al*., (2024) on purple passion fruit pulp reported similar findings (20). These three similar studies collectively identified the presence of flavonoids, phenolics, alkaloids, and phenols in the respective plant parts.

The effectiveness of purple passion fruit peel extract demonstrates significant advantages compared to other natural materials. The SPF value of purple passion fruit peel extract at a concentration of 1,200 ppm is 20.086±1.696, which falls into the ultra-protection category. The minimum recommended SPF value is 2, and a test sample is considered to have good SPF efficacy when its value exceeds 15, placing it in the ultra-protection sunscreen category, which provides enhanced protection against long-term skin damage risks (21). This performance is comparable to that of purple passion fruit seed extract, which achieves a similar effect at a lower concentration of 500 ppm (11). Thus, the peel extract exhibits efficacy comparable to that of the seed extract, even though the latter requires a lower concentration (500 ppm) to achieve similar results.

This value is further supported by the %Te measurement at the same concentration, which is 0.697±0.149. This result falls into the "sunblock" category as it lies within the <1% range. The %Te value indicates that only a small fraction of UVB radiation is transmitted, thereby significantly minimising the risk of erythema (20). Furthermore, the extract's ability to protect the skin from UVA radiation is demonstrated by the %Tp values, which range from 3% to 40% across all tested concentrations. This range confirms the extract's classification as a "sunblock" and its effectiveness in preventing skin pigmentation caused by UVA exposure (7). The %Tp measures how effectively a compound protects the skin from UVA radiation within the wavelength range of 320.5–375.5 nm, which can cause skin darkening. A lower %Tp value corresponds to a higher level of protection, whereas a higher %Tp value indicates lower protective efficacy (11).

The proportional increase in extract concentration, which corresponds to a higher SPF and lower %Te and %Tp, indicates that the active compounds directly enhance the photoprotective capability (22). This supports the concept that a higher content of UV-absorbing compounds leads to a greater amount of radiation energy being blocked (23). However, a noteworthy aspect is sustainability, as the passion fruit rind, an agricultural by-product, demonstrates superior efficiency compared to other parts of the fruit. The combination of a high SPF value with low %Te and %Tp values makes this extract suitable for broad-spectrum daily protection products. These characteristics make it ideal for use in formulations aimed at preventing photoageing, hyperpigmentation, and UV-induced DNA damage (24). Statistically, the One-Way ANOVA results indicated significant differences among the extract concentrations for SPF, %Te, and %Tp ($p<0.05$). These findings reinforce that the difference in concentration directly influences the sunscreen's effectiveness.

In conclusion, the ethanol extract of purple passion fruit rind demonstrates strong potential as an effective natural sunscreen agent for protecting the skin against both UVB and UVA radiation. Its flavonoid and phenolic content has been shown to contribute significantly to this photoprotective activity, as supported by consistent SPF, %Te, and %Tp test results and statistically significant analyses. However, further research on its photostability and long-term efficacy is necessary before this extract can be optimally utilised in natural ingredient-based sunscreen formulations.

CONCLUSION

The purple passion fruit peel extract has been shown to be an effective natural sunscreen, with an SPF of 20.086±1.696 at a concentration of 1,200 ppm. This extract can block 99.303±0.149% (%Te: 0.697±0.149) of skin-reddening radiation and 95.587±0.594% (%Tp: 4.413±0.594) of pigmentation-triggering radiation. Its flavonoid and phenolic content functions as both UV absorbers and antioxidants, offering dual protection against UV damage. This natural material has the potential to become a safe and sustainable alternative for commercial sunscreen formulations.

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