

Antioxidant activity and *in vitro* photoprotective potential of *Pereskia aculeata* as a natural ingredient for dermocosmetic applications

Atividade antioxidante e potencial fotoprotetor *in vitro* de *Pereskia aculeata* como ingrediente natural para aplicações dermocosméticas

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Abstract

This study aimed to evaluate the *in vitro* photoprotective potential of the hydroethanolic extract of *Pereskia aculeata* leaves. The antioxidant capacity and *in vitro* sun protection factor of the extract were evaluated using DPPH, FRAP, and ABTS assays, along with phytochemical characterization. The results demonstrated a concentration-dependent increase in antioxidant activity, with high levels of total phenolics, flavonoids, and carotenoids. At a concentration of 0.5%, the extract exhibited a sun protection factor greater than 10, indicating moderate ultraviolet protection. These findings suggest that *Pereskia aculeata* extract is a promising natural candidate for the development of dermocosmetic products with combined antioxidant and photoprotective effects.

Keywords: Natural Products; Antioxidants; Ultraviolet Radiation; Sun Protection Factor; Medicinal Plants.

Resumo

Este estudo teve como objetivo avaliar o potencial fotoprotetor *in vitro* do extrato hidroetanólico das folhas de *Pereskia aculeata*. A capacidade antioxidante e o fator de proteção solar *in vitro* do extrato foram avaliados por meio dos ensaios DPPH, FRAP e ABTS, juntamente com a caracterização fitoquímica. Os resultados demonstraram aumento da atividade antioxidante de forma dependente da concentração, com elevados teores de compostos fenólicos totais, flavonoides e carotenoides. Na concentração de 0,5%, o extrato apresentou fator de proteção solar superior a 10, indicando proteção moderada contra a radiação ultravioleta. Esses achados sugerem que o extrato de *Pereskia aculeata* é um candidato promissor para o desenvolvimento de produtos dermocosméticos com efeitos antioxidantes e fotoprotetores combinados.

Palavras-chave: Produtos Naturais; Antioxidantes; Radiação Ultravioleta; Fator de Proteção Solar; Plantas Medicinais.

Resumen

Este estudio tuvo como objetivo evaluar el potencial fotoprotector *in vitro* del extracto hidroetanólico de hojas de *Pereskia aculeata*. La capacidad antioxidante y el factor de protección solar *in vitro* del extracto fueron evaluados mediante ensayos DPPH, FRAP y ABTS, junto con la caracterización fitoquímica. Los resultados mostraron un aumento de la actividad antioxidante dependiente de la concentración, con altos niveles de compuestos fenólicos totales, flavonoides y carotenoides. A una concentración del 0,5%, el extracto presentó un factor de protección solar superior a 10, indicando una protección moderada contra la radiación ultravioleta. Estos resultados sugieren que el

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extracto de *Pereskia aculeata* es un candidato prometedor para el desarrollo de productos dermocosméticos con efectos antioxidantes y fotoprotectores combinados.

Palabras clave: Productos Naturales; Antioxidantes; Radiación Ultravioleta; Factor de Protección Solar; Plantas Medicinales.

1. Introduction

The skin is the largest organ of the human body, performing vital functions of protection, regulation, and sensory perception. However, its continuous exposure to environmental agents, especially ultraviolet (UV) radiation, makes it highly susceptible to structural and functional changes (Tang et al., 2024). Excessive sun exposure, which has intensified in recent decades due to increased UV-B radiation resulting from ozone layer depletion, has been associated with a range of dermatological disorders, including premature skin aging (photoaging), hyperpigmentation, chronic inflammation, local immunosuppression, and skin cancers such as melanoma and basal cell carcinoma (Ahmed et al., 2020; Brar et al., 2025).

As a primary preventive strategy against the harmful effects of UV radiation, the use of sunscreens has become a routine recommendation in clinical dermatology. These products act through the absorption, dispersion, or reflection of UV rays and are formulated with sunscreen agents classified mainly as organic (chemical) or inorganic (physical) filters (Nitulescu et al., 2023). Organic filters, such as octinoxate, oxybenzone, and avobenzone, are synthetic compounds that selectively absorb UV radiation, converting it into thermal energy. Inorganic filters, such as zinc oxide and titanium dioxide, function as physical barriers, reflecting incident radiation on the skin (Ballestín & Bartolomé, 2023; Araki et al., 2025).

Despite the recognized efficacy of these synthetic filters, several studies have warned about their potential adverse effects on human health and the environment (Wirtu, 2024). Substances such as oxybenzone and octinoxate have been associated with endocrine toxicity, estrogenic activity, and bioaccumulation, with evidence of negative impacts on the reproductive system and embryonic development. Studies have also shown that these compounds can penetrate the epidermis and be detected in the bloodstream, breast milk, and urine, reinforcing concerns about their long-term safety (Ballestín and Bartolomé, 2023). Additionally, there is growing evidence of the environmental impact caused by these filters, particularly in aquatic ecosystems, where they can impair fish reproduction, cause deformities in mollusks, and contribute to coral bleaching even at very low concentrations (Chatzigianni et al., 2022).

Given these limitations, scientific research and the cosmetics industry have focused on developing safer and more environmentally sustainable sunscreens (Tanveer et al., 2023). In this context, plant extracts and natural bioactive compounds have gained attention in the development of multifunctional dermocosmetic formulations. Substances such as flavonoids, anthocyanins, and carotenoids, widely present in fruits, vegetables, and medicinal plants, not only have the ability to absorb UV radiation, acting as natural filters, but also exhibit potent antioxidant activity, protecting the skin against the harmful effects of reactive oxygen species (ROS) generated by radiation (Lu et al., 2021).

Among the various plants with photoprotective potential, those that combine ease of cultivation, phytochemical richness, and safety of use are especially notable. *Pereskia aculeata* Miller, popularly known as ora-pro-nobis, belongs to the Cactaceae family. It is a non-conventional food plant (PANC) native to Brazil, cultivated in a rustic manner in several regions of the country, especially in-home gardens and urban vegetable plots (Maciel et al., 2021; Hoff et al., 2022).

P. aculeata has high nutritional value, being a relevant source of proteins, fibers, vitamins (A, C, and E), and minerals (calcium, zinc, and magnesium). Studies have shown that the leaves of this species are rich in antioxidant compounds such as polyphenols, carotenoids, and flavonoids, which provide the plant with cytoprotective, anti-inflammatory, and antimutagenic properties (Nogueira Silva et al., 2023). Among these compounds, flavonoids stand out as natural photoprotective agents due

to their ability to absorb light in the UV-A and UV-B ranges, in addition to directly inhibiting lipid peroxidation induced by UV radiation (Ciríaco et al., 2023).

Although there is promising scientific evidence regarding the antioxidant and pharmacological activity of *P. aculeata*, studies systematically evaluating its potential as a photoprotective agent are still scarce. Phytochemical characterization of the plant, combined with *in vitro* evaluation of the sun protection factor (SPF), is essential to validate its use in natural and sustainable dermocosmetic formulations. In this sense, determining the levels of total phenolics, flavonoids, and carotenoids, along with spectrophotometric evaluation of SPF, provides important support for the development of effective plant-based sunscreens (Chen et al., 2021; Choi et al., 2023).

Considering the growing global demand for natural cosmetics, the increasing value placed on sustainable ingredients, and the need for alternatives to synthetic filters, this study aimed to evaluate the *in vitro* photoprotective potential of the hydroethanolic extract of *P. aculeata* leaves. To this end, in addition to SPF determination, phytochemical analyses were performed to quantify total phenolics, flavonoids, and carotenoids, as well as antioxidant activity assays, in order to understand the mechanisms related to its photoprotective action and its multifunctional potential in cosmetic formulations.

2. Methodology

An experimental, laboratory-based study was conducted using a quantitative approach (Risemberg et al., 2026; Pereira et al., 2018), employing descriptive statistics with data classes based on extract concentration, mean and standard deviation values, as well as absolute and percentage frequencies (Shitsuka et al., 2014).

2.1 Collection and Preparation of *P. aculeata* Leaves

The leaves of *P. aculeata* were collected from specimens cultivated in the greenhouse of the Botany Laboratory at the Universidade do Vale do Sapucaí (UNIVÁS), Pouso Alegre, Minas Gerais, Brazil. The leaves were separated, washed, and dried in a forced-air oven at an average temperature of 40 °C for 36 hours.

2.2 Preparation of *P. aculeata* Extract

Extraction was performed according to the method optimized by Junior et al. (2013). The dried leaves were blended for 10 minutes. The plant material was homogenized with water at a ratio of 1:10 (plant mass: water), and the mixture was stirred with a magnetic stirrer for 6 hours at a temperature between 50 °C and 60 °C. Afterward, an equal volume of water was added, and the mixture was filtered twice with a sieve and once with voile fabric. To the remaining liquid, 96% ethanol was added at a ratio of 3:1 (alcohol: solution) and stored in the refrigerator for at least 12 hours at a temperature between 3 °C and 10 °C. After refrigeration, the solution was filtered again using voile fabric, and the precipitate (final extract) was retained on the fabric for 30 minutes to release excess water. The precipitate was then stored in a refrigerator for subsequent spectrophotometric testing.

2.3 Determination of Antioxidant Activity

2.3.1 DPPH Radical Scavenging Activity

The antioxidant capacity in scavenging the DPPH (2,2-diphenyl-1-picrylhydrazyl) free radical was assessed using the method described by Blois (1958) with some modifications. A reaction mixture containing 1 mL of acetate buffer (100 mM, pH 5.5), 1.25 mL of absolute ethanol, 250 µL of ethanolic DPPH solution (500 µM), and 50 µL of extract (diluted in ethanol at different concentrations) was vortexed and left to rest for 30 minutes in low-light conditions. DPPH has a maximum

absorbance at 517 nm, which decreases in the presence of hydrogen-donating (H^+) molecules, indicated by a color change from purple to yellow. Absorbance was measured using a UV-visible spectrophotometer at 517 nm. All measurements were performed in triplicate for statistical analysis. The DPPH radical scavenging activity was expressed as a percentage and calculated using the equation:

$$\text{Antioxidant activity(\%)} = \frac{A_{\text{control}} - A_{\text{sample}}}{A_{\text{control}}} \cdot 100$$

Where: A_{control} is the absorbance of the control (containing all reagents except the sample), and A_{sample} is the absorbance of the sample after 30 minutes. Trolox, a water-soluble analog of vitamin E, was used as a positive control.

2.3.2 Antioxidant Activity by the FRAP Method

To determine antioxidant activity via the Ferric Reducing Antioxidant Power (FRAP) method, the methodology described by Kukić et al. (2008) was used, with some modifications. This method is based on the direct measurement of the ability of antioxidants (reducing agents) in the sample to reduce, in an acidic medium (pH 3.6), the Fe^{3+} -TPTZ complex to Fe^{2+} , which has an intense blue color and maximum absorption at 593 nm. The FRAP reagent was freshly prepared at the time of analysis by mixing 25 mL of acetate buffer (300 mM, pH 3.6), 2.5 mL of TPTZ solution (10 mM TPTZ in 40 mM HCl), and 2.5 mL of $FeCl_3$ (20 mM) in aqueous solution. A 100 μ L aliquot of the diluted extract was added to 3 mL of the FRAP reagent and incubated at 37 °C in a water bath for 30 minutes. After this period, absorbance readings were taken, and the spectrophotometer was zeroed with the FRAP solution. The calibration curve was obtained using ferrous sulfate (100–2,000 μ M), and the results were expressed in μ mol Fe^{2+} /mg of sample.

2.3.3 Antioxidant Activity by the ABTS^{•+} Method

The antioxidant activity by the ABTS^{•+} method [2,2'-azinobis-(3-ethylbenzothiazoline-6-sulfonic acid)] was performed according to the methodology described by Rufino et al. (2007). The ABTS^{•+} radical was formed by reacting a 7 mM ABTS solution with a 140 mM potassium persulfate solution, incubated at 25 °C in the dark for 12 to 16 hours. Once formed, the radical was diluted with analytical grade ethanol until reaching an absorbance value of 0.700 ± 0.020 at 734 nm. In a dark environment, a 30 μ L aliquot of each extract dilution was transferred to test tubes containing 3.0 mL of the ABTS^{•+} radical solution. The reading was taken 6 minutes after the start of the reaction, at 734 nm, using ethanol as a blank. Trolox, a synthetic antioxidant analog of vitamin E, was used as a reference at concentrations of 100–2,000 μ M. The antioxidant activity results were expressed in μ mol of Trolox/mg of sample (Trolox equivalent antioxidant activity).

2.4 Determination of Total Phenolics

The total phenolic content was determined according to the method described by Swain and Hills (1959). The extract was diluted to different concentrations, and 0.5 mL of each was mixed with 0.5 mL of Folin-Ciocalteu reagent. After homogenization and a 3-minute rest, 1.0 mL of 20% sodium carbonate (Na_2CO_3) solution and 8.0 mL of distilled water were added, totaling 10.0 mL. For the blank, extract volume was replaced with purified water. After a 1-hour incubation in the dark, absorbance readings were taken in triplicate at 720 nm using a spectrophotometer. Gallic acid was used as the standard at concentrations of 2, 5, 10, 15, and 20 μ g/mL to construct the calibration curve. The total phenolic content was calculated from the regression equation and expressed as mg gallic acid equivalents (GAE)/100 g of sample.

2.5 Determination of Flavonoids

Total flavonoid content was determined following the method proposed by Woisky and Salatino (1998). A 0.5 mL aliquot of each extract dilution was mixed with 0.5 mL of 2% (w/v) aluminum chloride (AlCl_3) solution prepared in methanol. After 30 minutes of incubation at room temperature in the dark, absorbance was measured at 420 nm. Results were expressed as milligrams of quercetin equivalent per gram of dry extract (mg QE/g dry extract).

2.6 Determination of Carotenoid Content

Total carotenoid content was determined by spectrophotometry following the methodology proposed by Rodriguez-Amaya (2001). *Lycopene* was measured at 470 nm and β -carotene at 450 nm. The carotenoid content was calculated using the following equation:

$$\text{Carotenoid content (mg/100g)} = \frac{A \cdot V \cdot 1.000.000}{A_{1\text{cm}}^{1\%} \cdot M \cdot 100}$$

Where: A is the absorbance at the corresponding wavelength (470 nm for lycopene and 450 nm for β -carotene); V is the final volume of the solution (mL); $A_{1\text{cm}}^{1\%}$ is the extinction coefficient or molar absorptivity (3450 for lycopene and 2592 for β -carotene); and M is the sample mass (g).

2.7 In Vitro SPF Determination

SPF was determined using the in vitro spectrophotometric method. The extract was diluted in 70% ethanol to a final concentration of 0.2 mg/mL. Absorbances were measured from 290 nm to 320 nm at 5 nm intervals, using the same solvent as the blank. The SPF was calculated using the equation proposed by Mansur et al. (1986):

$$FPS_{(290-320)} = FC \sum_{290}^{320} P_i \cdot ABS_i$$

Where: FC is the correction factor (equal to 10); EE (λ) is the erythemal effect of the radiation at wavelength λ , as defined in Table 1; I(λ) is the solar intensity at wavelength λ , as defined in Table 1; Abs(λ) is the spectrophotometric absorbance reading of the sample at wavelength λ .

Table 1: Relationship between erythemal effect and radiation intensity per wavelength

λ (nm)	EE (λ) · I (λ)
290	0.0150
295	0.0817
300	0.2874
305	0.3278
310	0.1864
315	0.0839
320	0.0180
	1.0000

Source: Authors.

2.8 Statistical analysis

Data were expressed as mean $\pm$ standard deviation. Statistical analyses were performed using OriginLab Pro® 2018 software (OriginLab, USA). The data were analyzed by one-way Analysis of Variance (ANOVA), followed by Tukey's post-hoc test with a significance level of $p \leq 0.05$.

3. Results and Discussion

3.1 Antioxidant Activity of *Pereskia aculeata* Extract

The antioxidant activity of the *P. aculeata* extract was evaluated using DPPH, FRAP, and ABTS assays, revealing a concentration-dependent increase in all methods, as shown in Table 2. In the DPPH assay, an increase in free radical scavenging capacity was observed, rising from 74.03% at 1.00% concentration to 77.90% at 5.00%, indicating possible saturation at higher levels. In the FRAP assay, the extract's reducing capacity increased significantly, from 539.4 $\mu\text{mol Fe}^{2+}/\text{mg}$ at 0.25% to 808.3 $\mu\text{mol Fe}^{2+}/\text{mg}$ at 0.50%, suggesting a strong electron-donating ability. Finally, the ABTS assay also demonstrated increasing antioxidant activity, with values ranging from 251 $\mu\text{mol Trolox}/\text{mg}$ at 0.25% to 956 $\mu\text{mol Trolox}/\text{mg}$ at 0.50%, confirming the antioxidant potential of the extract.

Table 2: Antioxidant activity of *Pereskia aculeata* extract evaluated by DPPH, FRAP, and ABTS methods.

Sample	Concentration (%)	Antioxidant activity DPPH (%)	Antioxidant activity (FRAP ¹)	Antioxidant activity (ABTS ²)
<i>Pereskia aculeata</i> extract	0.25	-	539.40 $\pm$ 5.73 ^a	251.00 $\pm$ 2.51 ^a
	0.50	-	808.30 $\pm$ 4.71 ^b	956.00 $\pm$ 7.24 ^b
	1.00	74.03 $\pm$ 3.14 ^a	-	-
	2.50	77.63 $\pm$ 5.63 ^b	-	-
	5.00	77.90 $\pm$ 2.51 ^b	-	-

Where: Values are expressed as mean $\pm$ standard deviation. ¹ $\mu\text{mol Fe}^{2+}/\text{mg}$; ² $\mu\text{mol Trolox}/\text{mg}$. Identical letters in the same column indicate no significant differences between means by Tukey's test ($p \leq 0.05$). Source: Authors.

These results are consistent with recent studies that identified phenolic compounds and flavonoids as the main contributors to the antioxidant activity of *P. aculeata*. For instance, Costa et al. (2024) identified caffeic acid as the main phenolic compound in the leaves of the species, accounting for approximately 46.00%, followed by quercetin-3-O-rutinoside (14.99%) and isorhamnetin-O-pentoside-O-rutinoside (9.56%). In addition, Uwineza et al. (2021) reported that fractions obtained with solvents of medium to high polarity exhibited greater antioxidant activity in DPPH, ABTS, and FRAP assays, with emphasis on the acetone fraction, which showed an antioxidant capacity of 1095 $\mu\text{mol FeSO}_4/\text{g}$ in the FRAP method.

The strong antioxidant activity observed suggests that *P. aculeata* extract has a phytochemical profile rich in bioactive compounds capable of neutralizing ROS, which is essential in preventing skin photoaging (Turcov et al., 2023). These properties position the extract as a promising candidate for use in natural dermocosmetic formulations, aligned with the growing demand for plant-based ingredients with proven efficacy.

3.2 Determination of Total Flavonoids and Phenolics in the *Pereskia aculeata* Extract

The quantification of total phenolic compounds and total flavonoids present in the hydroethanolic extract of *P. aculeata* revealed a significantly increasing pattern as a function of the extract concentration, as shown in Table 3. The total phenolic content ranged from 10.25 $\mu\text{g}/\text{mL}$ at the 0.5% concentration to 267.45 $\mu\text{g}/\text{mL}$ at 5%, while total flavonoids increased

from 7.45 µg/mL to 74.57 µg/mL at the same concentrations. This behavior indicates a high presence of secondary metabolites with bioactive potential, with emphasis on flavonoids, whose concentration increased approximately tenfold.

Table 3: Total phenolic and flavonoid content in *Pereskia aculeata* extract.

Extract concentration (%)	Total flavonoids (Quercetin µg/mL)	Total phenolics (Gallic acid µg/mL)
0.05	7.45 ± 1.16 ^a	10.25 ± 1.23 ^a
1.00	14.90 ± 1.74 ^a	53.13 ± 1.11 ^b
2.50	37.29 ± 1.39 ^b	133.64 ± 2.03 ^c
5.00	74.57 ± 2.21 ^c	267.45 ± 1.46 ^d

Where: Values are expressed as mean ± standard deviation. Identical letters in the same column indicate no statistically significant difference between groups according to Tukey's test ($p \leq 0.05$). Source: Authors.

The levels observed in this study are compatible with those reported in the literature. Ciríaco et al. (2023) showed that *P. aculeata* flour presented 68.75 mg of flavonoids and 102.34 mg of total phenolics per 100.00 g of sample, highlighting the species' high antioxidant potential, attributed to the presence of quercetin, kaempferol, and their glycosylated derivatives. Similarly, Nogueira Silva et al. (2023) reviewed the plant's chemical composition and emphasized its phytochemical profile rich in polyphenols and flavonoids, reinforcing its promising use as a functional and dermocosmetic ingredient. Flavonoids, in particular, have been widely investigated for their ability to absorb UV radiation and inhibit oxidative reactions associated with skin aging and inflammation (Domaszewska-Szostek et al., 2021).

The correlation between high levels of phenolic and flavonoid compounds and the antioxidant activity results described previously supports the hypothesis that these metabolites act synergistically in neutralizing free radicals. This property is fundamental for dermocosmetic formulations aimed at protecting against environmental stressors such as UV radiation and delaying signs of skin aging. The significant presence of these compounds in the *P. aculeata* extract consolidates its multifunctional potential, combining antioxidant and photoprotective action in a single plant-based ingredient (Ghazi, 2022; Budzianowska et al., 2025).

3.3 Determination of Carotenoid Content in the *Pereskia aculeata* Extract

The quantification of total carotenoids in the *P. aculeata* extract showed a significant result when analyzed in its pure form, with values statistically higher than the diluted concentrations, as described in Table 4. Contents ranged from 0.002 µg/g at the 0.50% concentration to 0.033 µg/g at 5%, reaching a maximum of 0.543 µg/g in the pure extract sample.

Table 4: Total carotenoid content (µg/g) in *Pereskia aculeata* extract.

Extract concentration (%)	Total carotenoids (Carotenoids µg/g)
0.50	0.002 ± 2.13 ^a
1.00	0.004 ± 1.89 ^a
2.50	0.017 ± 2.04 ^a
5.00	0.033 ± 1.74 ^a
Pure	0.543 ± 1.59 ^b

Where: Values are expressed as mean ± standard deviation. Identical letters in the same column indicate no statistically significant difference between groups according to Tukey's test ($p \leq 0.05$). Source: Authors.

Carotenoids are natural pigments widely recognized for their antioxidant and photoprotective properties. Studies indicate that these compounds act as natural sunscreens by absorbing UV radiation and protecting cellular structures against damage induced by ROS (Chen et al., 2021). Specifically, β -carotene and lycopene are frequently associated with preventing skin photoaging by promoting membrane stability and reducing ultraviolet-induced DNA (deoxyribonucleic acid) damage (Ghazi, 2022). The presence of carotenoids in plant extracts is, therefore, considered strategic for developing natural dermocosmetic formulations, especially in synergy with phenolic compounds and flavonoids (Darvin et al., 2022).

The presence of carotenoids in *P. aculeata* extract, especially in the pure sample, reinforces the plant's multifunctional potential for topical applications. In addition to their direct antioxidant effect, carotenoids can contribute to the oxidative stability of cosmetic emulsions and broaden the extract's natural photoprotection spectrum. Thus, their inclusion in plant-based photoprotective formulations becomes an interesting and sustainable alternative to conventional synthetic filters, particularly in the context of the growing demand for natural cosmetics (Michalak et al., 2023).

3.4 Sun Protection Factor

The photoprotective capacity of the *P. aculeata* extract was determined using the in vitro spectrophotometric method, following the model proposed by Mansur et al. (1986). The 0.50% concentration of the extract showed a calculated SPF of 10.17 (Erro! Fonte de referência não encontrada. 5), which falls within the moderate protection range according to ANVISA (Agência Nacional de Vigilância Sanitária), the Brazilian Health Regulatory Agency responsible for overseeing cosmetic and pharmaceutical product standards. This result highlights the extract's potential as an active ingredient in cosmetic formulations with sun protection properties.

Table 5: Sun Protection Factor for *Pereskia aculeata* extract.

Weighted Values		Ora-pro-nobis Extract - Concentration 0,5%			
λ/nm	EE · I	Abs ₁	Abs ₂	Abs _{mean}	Abs · EE · I
290	0.0151	1.0711	1.0891	1.0801	0.0163
295	0.0817	1.0444	1.0618	1.0531	0.0860
300	0.2874	1.0231	1.0403	1.0317	0.2965
305	0.3278	1.0058	1.0221	1.0140	0.3324
310	0.1864	0.9905	1.0065	0.9985	0.1861
315	0.0839	0.9778	0.9936	0.9857	0.0827
320	0.0181	0.9651	0.9807	0.9729	0.0176
SPF (calculated)		10.1766			

Source: Authors.

The observed value may be directly related to the presence of bioactive compounds such as flavonoids, carotenoids, and phenolic acids already identified in the phytochemical analyses of this study. Flavonoids, in particular, have the ability to absorb UV radiation in the UV-A (320–400 nm) and UV-B (290–320 nm) ranges and also act as antioxidants, neutralizing reactive oxygen species generated by solar radiation (Domaszewska-Szostek et al., 2021; Milutinov et al., 2024). Complementarily, carotenoids contribute to the integrity of cell membranes and may reduce oxidative damage induced by UV, acting as an additional natural sunscreen (Darvin et al., 2022).

It is important to highlight that an SPF above 10 was achieved with a relatively low extract concentration (0.50%). Previous studies have shown that SPF tends to increase proportionally with extract concentration. For instance, Costa et al.

(2021) observed that formulations containing ethanolic extract of *Marcetia macrophylla* showed a significant increase in SPF as extract concentration increased from 5.00% to 30.00%, reaching values comparable to commercial sunscreens. These findings suggest that higher concentrations of *P. aculeata* extract may result in even greater SPF values, reinforcing its potential as an active ingredient in natural photoprotective formulations.

4. Conclusion

The *P. aculeata* extract exhibited significant antioxidant activity in the DPPH, FRAP, and ABTS assays, associated with high levels of phenolics, flavonoids, and carotenoids. It also showed an SPF greater than 10 at a 0.50% concentration, indicating its ability to absorb UV radiation. These results highlight the potential of the extract as an active ingredient in dermocosmetic formulations, combining antioxidant and photoprotective actions. It represents a natural, effective, and promising alternative in response to the growing demand for safe, sustainable, and multifunctional cosmetic products.

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References

- Ahmed, B., Qadir, M. I., & Ghafoor, S. (2020). Malignant melanoma: Skin cancer—diagnosis, prevention, and treatment. *Critical Reviews in Eukaryotic Gene Expression*, 30(4), 291–297. <https://doi.org/10.1615/CritRevEukaryotGeneExpr.2020028454>
- Araki, S. M., & Baby, A. R. (2025). New perspectives on titanium dioxide and zinc oxide as inorganic UV filters: Advances, safety, challenges, and environmental considerations. *Cosmetics*, 12(2), 77. <https://doi.org/10.3390/cosmetics12020077>
- Ballestín, S. S., & Bartolomé, M. J. L. (2023). Toxicity of different chemical components in sun cream filters and their impact on human health: A review. *Applied Sciences*, 13(2), 712. <https://doi.org/10.3390/app13020712>
- Blois, M. S. (1958). Antioxidant determinations by the use of a stable free radical. *Nature*, 181, 1199–1200. <https://doi.org/10.1038/1811199a0>
- Brar, G., Mehta, P., Bhatti, M., Kapoor, S., Manhas, A., & Singh, V. (2025). A comprehensive review of the role of UV radiation in photoaging processes between different types of skin. *Cureus*, 17. <https://doi.org/10.7759/cureus.81109>
- Budzianowska, A., Bujak, T., Sęczyk, Ł., Gromotowicz-Popławska, A., & Skiba, A. (2025). Antioxidants to defend healthy and youthful skin—Current trends and future directions in cosmetology. *Applied Sciences*, 15(5), 2571. <https://doi.org/10.3390/app15052571>
- Chatzigianni, M., Koltsakidou, K., Louka, M., Michailidis, K., Giannakou, I., & Kalantzi, O. I. (2022). Environmental impacts due to the use of sunscreen products: A mini-review. *Ecotoxicology*, 31, 1331–1345. <https://doi.org/10.1007/s10646-022-02592-w>
- Chen, X., Li, L., Su, L., Zhang, H., Li, Z., & Li, X. (2021). Interaction between flavonoids and carotenoids on ameliorating oxidative stress and cellular uptake in different cells. *Foods*, 10(12), 3096. <https://doi.org/10.3390/foods10123096>
- Choi, J., Kim, S. J., Kang, H. K., Yoon, H. J., & Kim, E. H. (2023). Comprehensive analysis of phenolic compounds, carotenoids, and antioxidant activities in *Lactuca sativa* var. *longifolia* cultivated in a smart farm system. *Processes*, 11, 2993. <https://doi.org/10.3390/pr11102993>
- Ciriaco, A. C. A., Mendes, R. M., & Carvalho, V. S. (2023). Antioxidant activity and bioactive compounds in ora-pro-nóbis flour (*Pereskia aculeata* Miller). *Brazilian Journal of Food Technology*, 26, e2022054. <https://doi.org/10.1590/1981-6723.05422>
- Costa, S. C. C., Pinto, J. E. B. P., Nascimento, E. A., Rosado, L. D., Costa, L. M., & Figueiredo, R. O. (2021). Evaluation of antioxidant, photoprotective and antinociceptive activities of *Marcetia macrophylla* extract: Potential for formulation of sunscreens. *Brazilian Journal of Biology*, 83, e246312. <https://doi.org/10.1590/1519-6984.246312>
- Darvin, M. E., Albrecht, H., Meinke, M. C., & Lademann, J. (2022). Carotenoids in human skin in vivo: Antioxidant and photoprotectant role against external and internal stressors. *Antioxidants*, 11(8), 1451. <https://doi.org/10.3390/antiox11081451>
- Domaszewska-Szostek, A., Puzianowska-Kuźnicka, M., & Kuryłowicz, A. (2021). Flavonoids in skin senescence prevention and treatment. *International Journal of Molecular Sciences*, 22(13), 6814. <https://doi.org/10.3390/ijms22136814>
- Ghazi, S. (2022). Do the polyphenolic compounds from natural products protect the skin from ultraviolet rays? *Results in Chemistry*, 4, 100428. <https://doi.org/10.1016/j.rechem.2022.100428>

- Hoff, R., Daguer, H., Deolindo, C. T. P., de Melo, A. P. Z., & Durigon, J. (2022). Phenolic compounds profile and main nutrients parameters of two underestimated non-conventional edible plants: *Pereskia aculeata* and *Vitex megapotamica* fruits. *Food Research International*, 162, 112042. <https://doi.org/10.1016/j.foodres.2022.112042>
- Junior, F. A. L., Pinto, J. E. B. P., Oliveira, A. F., Sales, M. B., & Cardoso, M. G. (2013). Response surface methodology for optimization of the mucilage extraction process from *Pereskia aculeata* Miller. *Food Hydrocolloids*, 33, 38–47. <https://doi.org/10.1016/j.foodhyd.2013.02.012>
- Kukić, J., Popović, V., Petrović, S., Mujević, M., Ćirić, A., & Soković, M. (2008). Antioxidant and antimicrobial activity of *Cynara cardunculus* extracts. *Food Chemistry*, 107, 861–868. <https://doi.org/10.1016/j.foodchem.2007.09.005>
- Lu, W., Shi, Y., Wang, R., Su, D., Tang, M., Liu, Y., & Li, Z. (2021). Antioxidant activity and health benefits of natural pigments in fruits: A review. *International Journal of Molecular Sciences*, 22, 4945. <https://doi.org/10.3390/ijms22094945>
- Maciel, V. B. V., Bezerra, R. Q., Chagas, E. G. L., Yoshida, C. M. P., & Carvalho, R. A. (2021). Ora-pro-nóbis (*Pereskia aculeata* Miller): A potential alternative for iron supplementation and phytochemical compounds. *Brazilian Journal of Food Technology*, 24, e2020180. <https://doi.org/10.1590/1981-6723.18020>
- Maciel, V. B. V., Bezerra, R. Q., Chagas, E. G. L., Yoshida, C. M. P., & Carvalho, R. A. (2021). Ora-pro-nóbis (*Pereskia aculeata* Miller): A potential alternative for iron supplementation and phytochemical compounds. *Brazilian Journal of Food Technology*, 24, e2020180. <https://doi.org/10.1590/1981-6723.18020>
- Michalak, M. (2023). Plant extracts as skin care and therapeutic agents. *International Journal of Molecular Sciences*, 24, 15444. <https://doi.org/10.3390/ijms242015444>
- Milutinov, J., Pavlović, N., Ćirin, D., Atanacković Krstonošić, M., & Krstonošić, V. (2024). The potential of natural compounds in UV protection products. *Molecules*, 29(22), 5409. <https://doi.org/10.3390/molecules29225409>
- Nitulescu, G., Lupuliasa, D., & Adam-Dima, I. (2023). Ultraviolet filters for cosmetic applications. *Cosmetics*, 10, 101. <https://doi.org/10.3390/cosmetics10040101>
- Nogueira Silva, N. F., Silva, S. H., Baron, D., Oliveira Neves, I. C., & Casanova, F. (2023). *Pereskia aculeata* Miller as a novel food source: A review. *Foods*, 12, 2092. <https://doi.org/10.3390/foods12112092>
- Pereira, A. S., Shitsuka, D. M., Parreira, F. J., & Shitsuka, R. (2018). *Metodologia da pesquisa científica*. Editora da UFSM.
- Risemberg, R. I. C., Wakin, M., & Shitsuka, R. (2026). A importância da metodologia científica no desenvolvimento de artigos científicos. *E-Acadêmica*, 7(1), e0171675. <https://eacademica.org/eacademica/article/view/675>
- Rodriguez-Amaya, D. B. (2001). *A guide to carotenoid analysis in foods*. International Life Sciences Institute Press.
- Rufino, M. S. M., Alves, R. E., Brito, E. S., Morais, S. M., Sampaio, C. G., & Jiménez, J. P. (2007). Determinação da atividade antioxidante total em frutas pela captura do radical livre ABTS⁺. *Comunicado Técnico 128*. Embrapa.
- Shitsuka, R. (2014). *Matemática fundamental para tecnologia* (2nd ed.). Editora Érica.
- Swain, T., & Hills, W. E. (1959). The phenolic constituents of *Prunus domestica*: The quantitative analysis of phenolic constituents. *Journal of the Science of Food and Agriculture*, 10, 63–68. <https://doi.org/10.1002/jsfa.2740100110>
- Tang, X., Wang, Y., Liu, L., Zhou, Z., Zhang, Y., & Luo, X. (2024). Current insights and future perspectives of ultraviolet radiation (UV) exposure: Friends and foes to the skin and beyond the skin. *Environment International*, 185, 108535. <https://doi.org/10.1016/j.envint.2024.108535>
- Tanveer, M. A., Rashid, H., & Tasduq, S. A. (2023). Molecular basis of skin photoaging and therapeutic interventions by plant-derived natural product ingredients: A comprehensive review. *Heliyon*, 9, e13580. <https://doi.org/10.1016/j.heliyon.2023.e13580>
- Turcov, D., Zbranca-Toporas, A., & Suteu, D. (2023). Bioactive compounds for combating oxidative stress in dermatology. *International Journal of Molecular Sciences*, 24, 17517. <https://doi.org/10.3390/ijms242417517>
- Uwineza, P. A., Gramza-Michałowska, A., Bryła, M., & Waśkiewicz, A. (2021). Antioxidant activity and bioactive compounds of *Lamium album* flower extracts obtained by supercritical fluid extraction. *Applied Sciences*, 11(16), 7419. <https://doi.org/10.3390/app11167419>
- Wirtu, Y. D. (2024). A review of environmental and health effects of synthetic cosmetics. *Frontiers in Environmental Science*, 12, 1402893. <https://doi.org/10.3389/fenvs.2024.1402893>
- Woisky, R. G., & Salatino, A. (1998). Analysis of propolis: Some parameters and procedures for chemical quality control. *Journal of Apicultural Research*, 37, 99–105. <https://doi.org/10.1080/00218839.1998.11100961>