



Tarenaya aculeata leaves: Potential uses in photoprotection and multifunctional products

Folhas de *Tarenaya aculeata*: Possibilidades de usos em fotoproteção e produtos multifuncionais

L. P. O. Silva¹; B. F. Duarte²; S. E. Lima-Junior¹; C. R. Nogueira²;
C. A. L. Cardoso^{1,2*}

¹Centro de Estudos em Recursos Naturais (CERNA), State University of Mato Grosso do Sul, 79804-970, Dourados, Mato Grosso do Sul, Brazil

²Programa de Pós-graduação em Química, Universidade Federal da Grande Dourados 79804-970, Dourados, Mato Grosso do Sul, Brazil

*claudia@uems.br

(Recebido em 25 de julho de 2025; aceito em 30 de agosto de 2026)

The photoprotective potential of plants has gained prominence in recent years as a more sustainable alternative to synthetic sunscreens. This study evaluated the relationship between phenolic compounds and flavonoids and their influence on the photoprotective potential of ethanolic extracts from *Tarenaya aculeata*. The research was conducted at two sites (A and B)—one urban and one rural—both located in Dourados, Mato Grosso do Sul, Brazil. The extract was prepared using ethanol via maceration for 24 hours. Subsequently, the extract was evaluated for Sun Protection Factor (SPF) in the 290–320 nm range, phenolic compound content (using the Folin-Ciocalteu method), and flavonoid content (using the aluminum chloride method); all analyses were performed via spectrophotometry. A relationship exists between compound levels and photoprotective activity, as the results indicated that higher levels of phenolic compounds led to increased photoprotective potential. Samples from both collection sites exhibited similar behavior. An 8 °C temperature fluctuation during the fifth week led to changes in the monitored parameters, suggesting an adaptive response to environmental shifts. This change in Week 5 marked the only period showing a statistically significant difference; it coincided with the onset of winter a season characterized by cold, dry weather hereby reinforcing the hypothesis of seasonal adaptation. The results demonstrate potential for future cosmetic applications, but further studies are needed to confirm their efficacy and safety in formulations.

Keywords: mussambê, phenolic compounds, flavonoids.

O potencial fotoprotetor das plantas tem ganhado destaque nos últimos anos como uma alternativa mais sustentável aos protetores solares sintéticos. Este estudo avaliou a relação entre os compostos fenólicos e flavonoides e sua influência no potencial fotoprotetor dos extratos etanólicos de *Tarenaya aculeata*. A pesquisa foi realizada em dois locais (A e B), um em área urbana e outro em área rural, ambos em Dourados – MS, Brasil. O extrato foi preparado em etanol por maceração por 24 horas. Após o extrato foi submetido a avaliação do fator de proteção solar (FPS) com leitura de 290-320 nm, compostos fenólicos pelo método de Folin- Ciocalteu e flavonoides usado o método do cloreto de alumínio e todas as análises foram realizadas por espectrofotometria. Há uma relação entre os teores de compostos e a atividade fotoprotetora, pois os resultados indicaram que maiores níveis de compostos fenólicos resultaram no aumento do potencial fotoprotetor. Os dois locais de coleta apresentaram um comportamento similar. A alteração de 8 °C na temperatura, na semana 5, propiciou a alteração de valores dos parâmetros monitorados sugerindo uma resposta adaptativa às mudanças ambientais. Essa alteração na Semana 5 conduziu ao único período com diferença estatística significativa, coincidindo com o início do inverno, estação marcada por clima frio e seco, o que reforça a hipótese de adaptação sazonal. Os resultados demonstram potencial para futuras aplicações cosméticas, mas são necessários mais estudos para confirmar sua eficácia e segurança em formulações.

Palavra-chave: mussambê, compostos fenólicos, flavonoides.

1. INTRODUCTION

Prolonged exposure to UV radiation is associated with cellular damage, including DNA mutations, making it one of the main risk factors for the development of skin cancer [1]. In this

context, the search for natural sources with biotechnological potential has become a promising strategy for developing sustainable products with applications in the cosmetic and pharmaceutical industries.

Exposure to UV radiation poses a major challenge to human health, driving the demand for natural photoprotective agents. Studies indicate that secondary metabolites, such as phenolic compounds and flavonoids, play a crucial role in absorbing UV radiation, contributing to the defense mechanisms of plants and potentially providing photoprotective benefits for topical applications [2]. In this regard, plant-based photoprotectors have gained prominence as a sustainable alternative to synthetic sunscreens. In addition to being rich sources of natural antioxidants, these compounds may reduce the adverse effects associated with conventional filters, such as skin irritation and environmental impacts, particularly in marine ecosystems [3]. Studies indicate that certain chemical filters, commonly used in commercial sunscreens, contribute to coral reef bleaching and may have a negative impact on aquatic organisms [4]. Thus, the partial or complete replacement of these compounds with plant extracts represents progress both for skin health and environmental preservation.

Previous studies reveal that plants with photoprotective activity have a chemical composition rich in phenolic compounds and flavonoids. In this context, *Tarenaya aculeata*, also known as mussambê and sojinha, is a species widely distributed in tropical regions and has gained interest due to the presence of bioactive metabolites of industrial relevance. Previous research has demonstrated that extracts of this species exhibit antioxidant and photoprotective properties and phenolic compounds and flavonoids which may enable their incorporation into cosmetic formulations [5-7]. Given this scenario, the present study aims to evaluate the relationship between the content of phenolic and flavonoid compounds and the photoprotective activity of ethanolic extracts of *T. aculeata*, contributing to the advancement of knowledge about its biotechnological potential and its applications in the cosmetic industry. Additionally, as *T. aculeata* is considered a "weed" and an invasive plant, this characteristic makes it easy to cultivate and propagate, which, in turn, is beneficial for product development, as it can be produced on a large scale under the right conditions. Studies such as those by Macedo and Martins (1998) [8] have already indicated the productive potential of weeds. Therefore, the species *T. aculeata* deserves attention regarding its possible biological potential.

2. MATERIAL AND METHODS

2.1 Sample Collection and Extract Preparation

Tarenaya aculeata leaves were collected weekly over six weeks, between May and July 2024, in two distinct locations in the municipality of Dourados, Mato Grosso do Sul, Brazil (2°13'18.54"S, 54°48'23.09"W). The two locations were: Site A (22°13'10.3"S, 54°49'45.5"W) and Site B (22°11'52.7"S, 54°55'51.3"W). The average temperature during the collection period was 28 ± 3 °C, whereas the temperature during the week 5 collection was 20 ± 1 °C.

Site A, located in an urban area of the municipality, was the initial collection point and the source of seedlings transplanted to Site B, corresponding to a rural area on the Federal University of Grande Dourados (UFGD) campus. The botanical material was duly recorded and deposited in the Herbarium of the Federal University of Grande Dourados (UFGD), with collection authorization registered under SISGEN. Collections were carried out weekly at both locations (A and B), totaling six sampling events. In each collection, three specimens of *T. aculeata* were selected, and three leaves were taken from each specimen. The selected leaves exhibited good integrity and vitality, avoiding possible contamination by pathogens. These leaves were used for extract preparation. For the preparation of ethanolic extracts, 0.17 g of plant material from each sample was manually ground and mixed with 5 mL of ethanol, remaining in contact for 24 hours until the filtration process. After 24 hours of extraction, filter paper filtration was performed, and the filtered samples were stored in a freezer for subsequent analysis.

Thus, the experimental protocol resulted in three extracts per site (A and B) for each collection, totaling three extracts per species. All analyses were conducted in triplicate and performed directly on the prepared extracts.

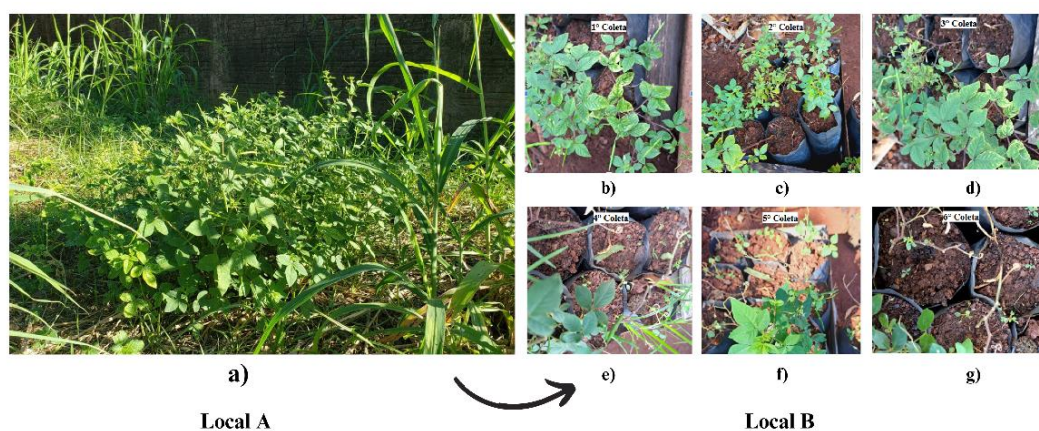


Figure 1: Graphic representation of the species of *Tarenaya aculeata* collected in a) Local A and b) Collect 1 from B, c) Collect 2 from B d) Collect 3 from B e) Collect 4 from B f) Collect 5 from B and g) Collect 6 from B.

2.2 Ultraviolet (UV) Scanning

The ethanolic extracts were scanned in duplicate using a UV/Vis spectrophotometer (Global Trade Technology). Measurements were taken at wavelengths ranging from 200 to 600 nm, with a resolution of 1 nm. The spectrum was used to determine the photoprotective properties.

2.3 Photoprotective Potential Analysis

The sun protection factor (SPF) was determined by ultraviolet (UV) spectrophotometric scanning, following the method proposed by Mansur et al. (1986) [9]. The analyses were conducted in the wavelength range of 290-320 nm, and the SPF values were calculated using Equation 1.

$$SPF = CF \times \sum_{290}^{320} EE(\lambda) \times I(\lambda) \times Abs(\lambda) \quad (1)$$

Where:

SPF = Solar Protection Factor

CF = Correction Factor (=10), determined according to the sunscreens' SPF known;

$I(\lambda)$ = Solar light intensity at wavelength (λ);

$EE(\lambda)$ = Erythemogenic effect of radiation at the wavelength (λ);

$Abs(\lambda)$ = Spectrophotometric absorbance Reading of the sunscreen solution at wavelength (λ).

The $EE(\lambda) \times I(\lambda)$ values used were previously described in the study by Sayre et al. (1979) [10].

2.4 Determination of Phenolic Compounds

For the analysis of phenolic compounds, 100 μ L of the sample was incubated with 500 μ L of Folin- Ciocalteu reagent (1:10 v/v) and 1000 μ L of distilled water [11]. After 1 minute, 1500 μ L of 20% (m/v) aqueous sodium carbonate was added to the solution and allowed to react for 2 hours. The sample absorbance was measured using a UV/Vis spectrophotometer (Global Trade Technology) at a wavelength of 760 nm, with ethanol as the blank. The calibration curve equation was obtained using gallic acid as the standard for quantification. Results were expressed as μ g of gallic acid equivalent per gram of extract (μ g GAE mL^{-1}).

2.5 Determination of Flavonoids

For flavonoid determination, a reaction was carried out between 1000 μL of the sample and 1000 μL of 2% aluminum chloride in methanol [11]. After 15 minutes, absorbance was measured using a UV/Vis spectrophotometer (Global Trade Technology) at 430 nm. A matrix solution was prepared using 1000 μL of the sample and 1000 μL of methanol to prevent interference from other compounds absorbing in the same region. This solution was also measured at 430 nm, and the obtained value was subtracted from the analysis results. Ethanol was used as the blank, and quantification was performed using a calibration curve with rutin as the standard. Results were expressed as μg of rutin equivalent per gram of extract ($\mu\text{g RE mL}^{-1}$).

2.6 Statistical Analysis

To assess whether the factors of location and time (weeks) significantly influenced the concentration of phenolic and flavonoid compounds in the samples, a two-way ANOVA was performed, followed by Tukey's post hoc test. These analyses were conducted using the software Statistica 14 [12].

3. RESULTS

3.1 Chemical composition and photoprotective analysis

Figure 2 presents the SPF values and phenolic and flavonoid compound levels over the weeks at the different collection sites, A and B. The analysis of figure 2 highlights that the three evaluated variables (SPF, phenolic compounds, and flavonoids) exhibited similar behavior over time, suggesting a possible correlation among them. Additionally, it was observed that both the SPF values and the chemical composition of the extracts were generally higher at Location A compared to Location B in most of the analyses conducted.

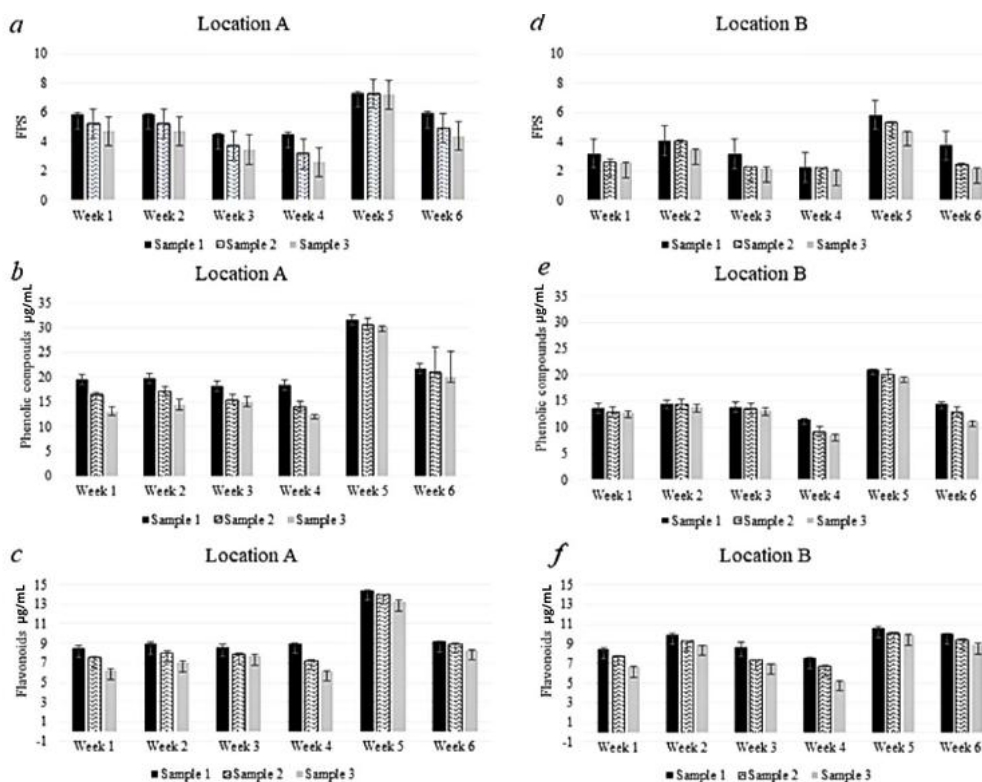


Figure 2: SPF values, phenolic compounds and flavonoid levels in *Tarenaya aculeata* from locations A and B.

3.2 Variance analysis and influence of the chemical composition

Analysis of variance allowed us to identify variations between collections, locations and how chemical compounds influenced photoprotection values. Figure 3a illustrates how phenolic compounds affected the response variable (SPF), while Figure 3b depicts the impact of flavonoids. Regarding phenolic compounds, no statistically significant difference was observed between Locations A and B for the first three collections. For flavonoids, a significant difference was observed only in the fifth collection.

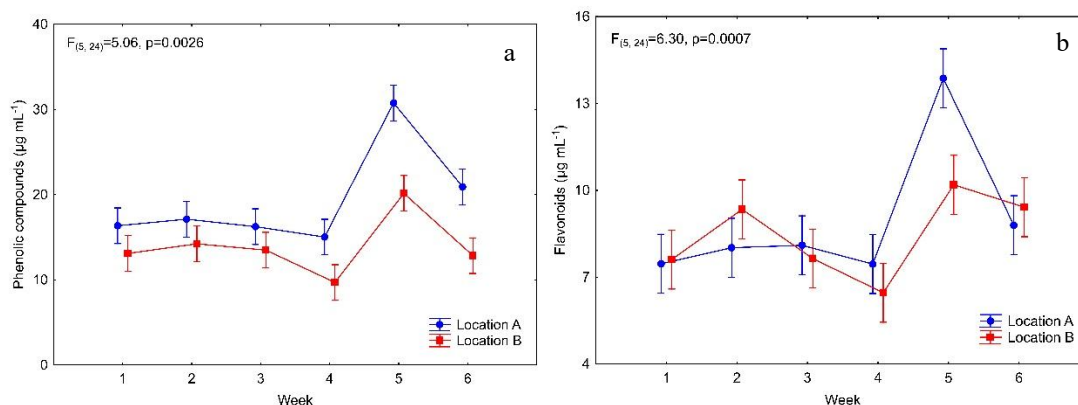


Figure 3. Analysis of variance results for the concentrations of a) phenolic compounds and b) flavonoids measured across six weekly collections in Locations A and B. Data are expressed as mean $\pm$ SD.

3.3 Analysis of absorbance in the UV region

The extracts of *T. aculeata* showed electromagnetic absorption in regions of 200 to 600 nm (Figure 4). Differences between collects and weeks were not substantial, with the greatest differences occurring in the 5 and 6 weeks.

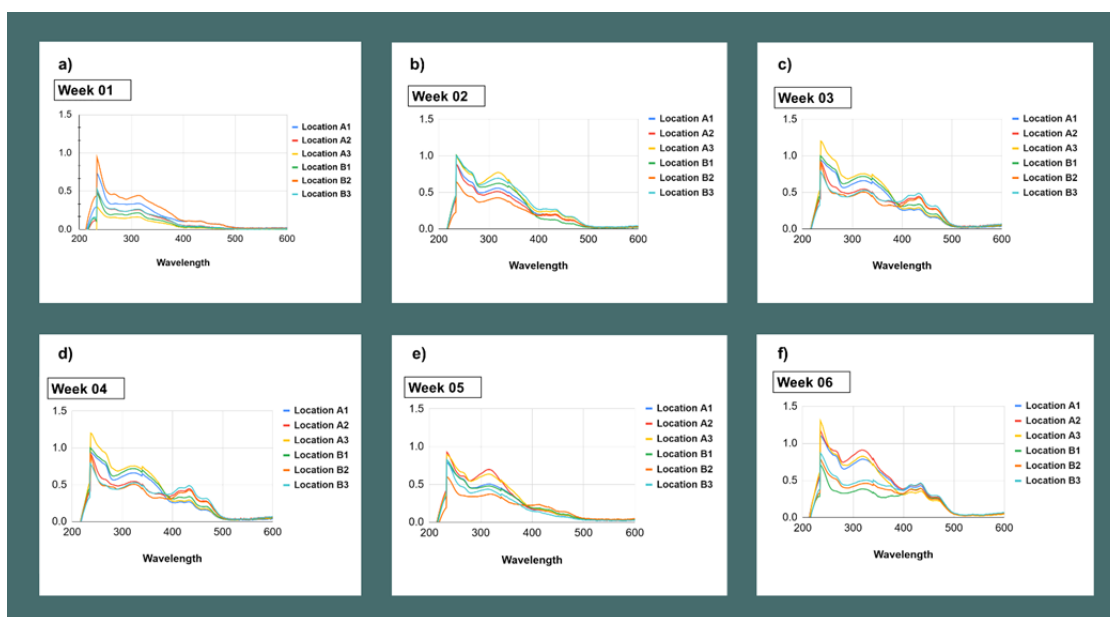


Figure 4. Ultraviolet (UV) scanning (from 200 to 600 nm) of the ethanolic extracts of *Tarenaya aculeata* across six weekly collections from local A and B.

4. DISCUSSION

From Figure 2, a greater variation in data can be observed in collections 5 and 6, which exhibited the highest levels of chemical compounds. A possible explanation for this difference is the temperature fluctuation throughout the collection period, which took place during the winter season, characterized by low rainfall and considerable daily thermal amplitude in Dourados, MS, Brazil [13].

The collections began in May, during autumn, while the fifth collection occurred on June 25, marking the beginning of winter, which may explain the changes in chemical composition at both locations A and B. Indeed, previous studies indicate that secondary metabolites can exhibit variations in their concentrations and structures in response to changes in environmental conditions within their habitat [14, 15].

Figure 1 illustrates the collection sites and highlights that *T. aculeata* specimens at Location B were transplanted from seedlings originating from Location A. Notably, from the fourth week onward, Location B began experiencing herbivore attacks. Initially, it was hypothesized that changes in metabolite levels might be positively associated to these attacks. However, since both Locations A and B exhibited the same increase in metabolite levels, the most plausible explanation for this variation is the influence of climatic factors

These findings underscore the resilience of the studied species, which maintained the production of essential metabolites even under herbivore pressure. This behavior aligns with previous studies on seasonal influence, which demonstrate that plants regulate metabolite production throughout the seasons as an adaptive strategy [12]. Additionally, as a weedy species, *T. aculeata* spreads easily and rapidly, which could be advantageous in producing potential bioproducts due to its ease of cultivation [8]. Based on the analyses performed, it was observed that as the concentration of phenolic compounds increased, the sun protection factor (SPF) also increased proportionally (Figure 2). The photoprotective behavior of the extracts appears to be closely related to the content of secondary metabolites. Previous studies with aqueous extracts and fractions of *T. aculeata* demonstrated that the fractions contained significantly higher concentrations of phenolic compounds (318.80 mg/g) compared to aqueous extracts (151.47 mg/g of gallic acid equivalents—GAE). These higher levels resulted in superior SPF values for the methanolic fraction (SPF: 16.93) compared to the aqueous extract (SPF: 8.14) and greater absorption in the UV-vis wavelength range. However, flavonoid levels did not differ statistically among the samples, suggesting that they did not significantly influence photoprotective activity [6].

Phenolic compounds and flavonoids contain chemical groups in their structures susceptible to ultraviolet (UV) radiation absorption. This chemical characteristic may enhance the photoprotective activity of extracts containing these classes of compounds. Thus, it is believed that the superior photoprotection observed in samples from the fifth collection is directly associated with the higher levels of phenolic compounds found in these samples.

Another important aspect is that variations in phenolic compound content directly impact SPF variation. The absorption wavelength range of phenolic compounds aligns with the UV spectrum (100–400 nm), covering UVC, UVB, and UVA. Among these, UVA penetrates the deepest into human skin. The phenolic compounds exhibit photoprotective properties because they can absorb ultraviolet energy and transform it into lower-energy radiation [2]. Overall, the ethanolic extracts of *T. aculeata* exhibited significant amounts of phenolic compounds and flavonoids, accompanied by promising photoprotection values. Previous studies on aqueous extracts from *T. aculeata* leaves have already demonstrated encouraging SPF values, including their incorporation into commercial creams, which showed good stability results [7]. In this study, the SPF values found for ethanolic extracts indicate a high potential for use in photoprotective formulations. According to ANVISA regulations [16] extracts with an SPF greater than 6 are suitable for use in photoprotection products.

The photoprotective activity observed in *T. aculeata* is a promising characteristic of this species, reinforcing previous studies and highlighting its potential for cosmetic applications. The use of *T. aculeata* extracts in cosmetic formulations, whether for product protection or the development of organic sunscreens, represents a sustainable alternative to reducing the

consumption of synthetic sunscreens. This substitution is crucial, given the environmental damage associated with synthetic products, particularly their impact on coral reefs [3, 4], which is vital in maintaining the planet's ecological balance. Although Local B presented SPF values below 6 (ranging from 5.81 to 4.70 in collection 5), these extracts still demonstrate promise for the development of multifunctional products. According to Resolution No. 30, dated June 1, 2012 [16], for a compound to be used as a multifunctional product, a minimum UVA photoprotection value of 2 is required, with these products intended for personal hygiene, cosmetics, and perfumery. Additionally, it is important to emphasize that their application is limited to formulation protection and does not confer photoprotective activity to the user.

Overall, the species exhibited little statistical variability throughout the collections, except for collections 5 and 6, which showed higher levels of chemical compounds and greater photoprotective activity. These results reinforce the potential of *T. aculeata* extracts for product protection, as their sun protection factor (SPF) demonstrated relative consistency, influencing making it a valuable attribute for formulations. Thus, the findings of this study not only confirm the species' photoprotective potential but also open new avenues for further research on its applications in various biotechnological and industrial contexts.

5. CONCLUSION

The ethanolic extracts of *T. aculeata* collected from different locations in the municipality of Dourados, MS, demonstrated a presence of phenolic compounds, flavonoids, and photoprotective properties. Furthermore, this study suggests that the content of compounds present in the samples may contribute to photoprotective potential.

The results demonstrate potential for future cosmetic applications, but further studies are needed to confirm their efficacy and safety in formulations.

6. ACKNOWLEDGMENTS

Fundação de Apoio ao Desenvolvimento do Ensino, Ciência e Tecnologia do Estado do Mato Grosso do Sul (FUNDECT), Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (CAPES) Finance Code 001 for the doctoral scholarship granted to BFD, Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq) for the research grant awarded to CALC (Process No. 306065/2025-8), and Universidade Estadual do Mato Grosso do Sul (UEMS) by scholarship for LPOS.

7. BIBLIOGRAPHIC REFERENCES

1. Yu ZW, Zheng M, Fan HY, Liang XH, Tang YL. Ultraviolet (UV) radiation: a double-edged sword in cancer development and therapy. *Mol Biomed*. 2024 Oct;5(1):49:1-24. doi: 10.1186/s43556-024-00209-8
2. Torres-Contreras AM, Garcia-Baeza A, Vidal-Limon HR, Balderas-Renteria I, Ramirez-Cabrera MA, Ramirez-Estrada K. Plant secondary metabolites against skin photodamage: Mexican plants, a potential source of UV-radiation protectant molecules. *Plants*. 2022 Jan;11(2):220:1-25. doi: 10.3390/plants11020220
3. Jesus A, Sousa E, Cruz MT, Cidade H, Lobo JMS, Almeida IF. UV filters: challenges and prospects. *Pharmaceutics*. 2022 Feb;15(3):263:1-26. doi: 10.3390/ph15030263
4. Carve M, Nugegoda D, Allinson G, Shimeta J. A systematic review and ecological risk assessment for organic ultraviolet filters in aquatic environments. *Environ Pollut*. 2021 Jan;268:115894. doi: 10.1016/j.envpol.2020.115894
5. Soares Neto RL, Thomas WW, Barbosa MRV, Roalson EH. New combinations and taxonomic notes for *Tarenaya* (Cleomaceae). *Phytotaxa*. 2018 Dec;32(4):540-5. doi: 10.1590/0102-33062017abb0417
6. Duarte BF, Aguayo de Castro, TL, Ventura AS, Nogueira CRN, Cardoso CAL. Comparison of the aqueous extraction methods of the *Tarenaya aculeata* leaves in relation to the chemical composition and photoprotector, antibacterial and antioxidant potentials. *Front, J Soc Technol Environ Sci*. 2023 Oct;12(13):90-105. doi: 10.21664/2238-8869.2023v12i3.p90-105

7. Duarte BF, Aguayo de Castro, TL, Ventura AS, Nogueira CRN, Cardoso CAL. Biological potentialities and chemical composition of *Tarenaya aculeata* roots and stems. Rev Colomb Quím. 2022 Mar;51(3):45-52. doi: 10.15446/rev.colomb.quim.v51n3.106229
8. Macedo JF, Martins RP. Potencial da erva daninha *Waltheria americana* (Sterculiaceae) no manejo integrado de pragas e polinizadores: visitas de abelhas e vespas. An Soc Entomol Bras. 1998 Mar;27:29-40. doi: 10.1590/S0301-80591998000100004
9. Mansur JDS, Breder MNR, Mansur MCA, Azulay RD. Determination of sun protection factor (SPF) of sunscreens by ultraviolet spectrophotometry. An Bras Dermatol. 1986;61(3):121-4.
10. Sayre RM, Agin PP, LeVee GJ, Marlowe E. A comparison of in vivo and in vitro testing of suncreening formulas Photochem Photobiol. 1979 Mar;29(1):559-66. doi: 10.1111/j.1751-1097.1979.tb07090.x
11. Djeridane A, Yousfi M, Nadjemi B, Boutassouna D, Stocker P, Vidal N. Antioxidant activity of some Algerian medicinal plants extracts containing phenolic compounds. Food Chem. 2006 Aug;97(4):654-60. doi: 10.1016/j.foodchem.2005.04.028
12. TIBCO Software Inc. Data Science Workbench. Version 14. 2020. Available from: <https://www.tibco.com/>.
13. Fietz CR, Fietz GF, Comunello E, Flumignan DL. O clima da região de Dourados, MS [Internet]. 3. ed. rev. e amp. Dourados (MS): Embrapa Agropecuária Oeste; 2017. (Documentos, 138). Disponível em: <https://www.embrapa.br/en/busca-de-publicacoes/-/publicacao/1079733/o-clima-da-regiao-de-dourados-ms>
14. Zakraoui M, Hannachi H, Pasković I, Vidović N, Polić Pasković M, Palčić I, et al. Effect of geographical location on the phenolic and mineral composition of Chetoui olive leaves. Foods, 2023 Jun;12(13):2565:1-15. doi: 10.3390/foods12132565
15. Chen J, Ning S, Lu X, Xiang W, Zhou X, Bu Y, et al. Variation in flavonoid and antioxidant activities of *Pyrrosia petiolosa* (Christ) Ching from different geographic origins. Frontiers in Plant Science. 2023 Apr;14:1173489. doi: 10.3389/fpls.2023.1173489
16. Agência Nacional de Vigilância Sanitária. Resolução - RDC nº 30, de 1º de junho de 2012. Aprova o Regulamento Técnico Mercosul sobre Protetores Solares em Cosméticos e dá outras providências. Brasília (DF): Diário Oficial da União; 2012. Available from: <https://kivalitaconsulting.com/wp-content/uploads/2024/09/RDC-30-12.pdf>.