Review Article

Plants from Brazil with Potential Photoprotective Activity: A Review

Thiago Portalda Paixão[1], Margareth Tavares Silva[2], Marcieni Ataide de Andrade[2], Nádia Rezende Barbosa Raposo[3], José Luiz Fernandes Vieira[1,*]

[1]Toxicology Laboratory, Faculty of Pharmacy, Federal University of Pará, Belém-PA, BRAZIL.
[2]Laboratory of Pharmaceutical Products of the Amazon, Faculty of Pharmacy, Federal University of Pará, Belém-PA, BRAZIL.
[3]Center for Research and Innovation in Health Sciences, Federal University of Juiz de Fora, Juiz de Fora-MG, BRAZIL.

ABSTRACT

Background: Skin cancer due the solar radiation is an important public health issue in Brazil. Sunscreen formulations protect the skin from the harmful effects of solar radiation. Plants products can have photoprotective compounds that can be incorporated into sunscreen formulations which attend a demand of society for the use of natural compounds in different cosmetics. This review aims to summarize studies that evaluated the photoprotective activity of plants in Brazil in the last ten years. **Materials and Methods:** A search was conducted in Medline, Scopus, and Embase databases, using the descriptors Brazilian natural products, photoprotection, natural sunscreen, plant extract, and photoprotective activity. **Results:** A total of 392 manuscripts were retrieved in the databases searched. After applying the criteria of inclusion and exclusion, thirty-six papers were selected, followed by a final screen resulting in twenty-nine. Plant extracts and oils were tested in these studies. The solar photoprotector factor was determined *in vitro* in most studies. Only three studies were performed in tests *in vivo* and there were no clinical studies with an adequate sample effort. **Conclusion:** Several plant extracts demonstrated promising solar photoprotective activity *in vitro*, such as *Erythrina velutina, Dalbergia monetaria*, and *Garcinia brasiliensis*, which recommend complementary studies for use in sunscreens formulations as most of the studies with Brazilian plants were focused on preliminary analyses in the last decade.

Keywords: Brazilian natural products, Photoprotection, Solar protection factor, Plants.

Correspondence:
José Luiz Fernandes Vieira
Toxicology Laboratory, Faculty of Pharmacy, Federal University of Pará, CEP 66075-110, Belém – PA – BRAZIL.
Email id: jvieira@ufpa.br

Received: 22-07-2022 ;
Revised: 26-09-2022 ;
Accepted: 10-10-2022.

INTRODUCTION

The harmful effects of solar radiation on the skin are well recognized and depend on varied factors, such as the skin phototype and length of sun exposure.[1] Ultraviolet radiations A (UVA) and B (UVB), infrared radiation, and visible light penetrate the skin at different depths, damaging cells. The most active radiation is UVB, which constitutes about 4-5% of solar emission and causes acute effects such as solar burn, erythema, and allergy. The UVA accounts for 90% of solar radiation and triggers chronic effects such as premature aging and skin cancer.[2,3]

Different mechanisms take part in skin damage, such as redox imbalance, inflammation, and alterations in pigmentation. Sunscreens prevent the effects of sunlight as the organic and inorganic filters difficult the penetration of solar radiation to different degrees of the skin. Sunscreens also may contain antioxidants, anti-inflammatories compounds, and modulators of tyrosinase enzyme.[4-6]

Brazil has a high annual incidence of sunlight, and non-melanoma skin cancer is the most prevalent malignancy in the country, accounting for almost 30% of notification of the disease, with 176.940 cases diagnosed in 2020.[2] Using sunscreens is high in the Brazilian population, and a promising issue is a search for plants with photoprotective activity to be incorporated into sunscreens formulations. The concept of green or natural cosmetics has favorable public acceptance and there is a crescent tendency to incorporate plant compounds with pharmacological activity into sunscreens formulations.[7-9]

The photoprotective, antioxidant, and anti-inflammatory activities of plant species from distinct Brazilian biomes were evaluated in previous studies. However, there is a lack of systematization and comparison of the data obtained. Thus, the study aimed to perform a comprehensive review of published studies in the last ten years that evaluated the photoprotective activity of plants in Brazil.

DOI: 10.5530/097627870191

LITERATURE REVIEW

Search strategy

The authors aimed to identify studies assessing the photoprotective activity of plants from Brazil. The keywords "Brazilian natural products, photoprotection, natural sunscreen, plant extract, and photoprotective activity" were searched in Medline (https://www.ncbi.nlm.nih.gov/pubmed), Embase (https://embase.com) and SCOPUS (https://www.scopus.com) databases. Studies were limited to those published from January 2011 to December 2021, with no language restrictions.

The studies included in the review were those performed with plants of Brazil, natives or not, and that have their photoprotective activity assessed by *in vitro* or *in vivo* methods.

Exclusion criteria were publications with no original research, studies with products other than plants, case reports, editorials, review articles, meta-analyses, abstracts, and conference proceedings.

Study Selection

Two independent reviewers (T.P.P., M.T.S.) analyzed all titles and abstracts of manuscripts selected in the databases searched to decide to refuse or include the manuscript in the review. A third reviewer (J.L.F.V.) resolved any disagreements about the inclusion or exclusion of studies that had an absence of consensus. Each abstract had reasons for exclusion clearly outlined according to the criteria of inclusion or exclusion. The manuscripts included were retrieved from databases and the reviewers read carefully the full text and checked for completeness and accuracy of the data. Information collected concerning the study plant included the botanical classification of the species, part of the plant, extract and their concentrations, solar protection factor (SPF), the assessment of photoprotective activity by *in vitro* or *in vivo* models, dose, formulation, and results.

RESULTS

The electronic search yielded 392 studies. Based on the titles and abstracts, the number decreased to 365 manuscripts, twenty-seven were replicates, thirty-six were selected and a final screen resulted in twenty-nine studies. Figure 1 shows a schematic depicting the selection process of the studies.

Of the selected study, twenty-four assessed plant extracts, two fractionated plant extracts, and three plant oils. A total of 13 (44.82%) studies evaluated plant extracts incorporated into cosmetic formulations and in 12 (41,37%) studies, the plant extracts were associated with chemical and/or physical filters. Three studies evaluated the photoprotective activity *in vivo*, one in an animal model and two in humans. Seventeen studies assessed the Sun Protection Factor (SPF) by spectral scan analysis and in four studies the diffuse transmittance spectroscopy estimates the SPF and the degree of UV protection. The cytotoxicity of plant extracts was assessed in four studies. In this review, SPF 6 was the minimum value to be considered as a potential photoprotective product according to the Brazilian regulatory agency.[10] Table 1 summarizes the photoprotective activity of plants included in the review.

Features of studies that evaluate the photoprotective activity of plants in Brazil

The non-melanoma cancer is a relevant public health issue in Brazil and dozens of studies evaluated different biological activities of plants from the Brazilian biomes, however, only a few studies evaluated the photoprotective activity of plants in Brazil. There were no clinical studies on healthy volunteers exposed to sunlight with an adequate sample effort as well as no commercial formulation with plant extracts for use as sunscreen was approved by the regulatory agency. This review found a broad spectrum of SPF among the plant extracts investigated, with some plants presenting promising activity. Incorporating plant extracts or oils in neutral formulations or organic and inorganic filters modify the SPF with positive results in most plant extracts.

The SPF of several plant extracts was low, such as the glycolic extract at 1% from *Theobroma cacao* L. of 2.4, which was associated with the low concentration of the plant extract tested.[11] Methanolic and glycolic extracts from the leaf of *Passiflora coccinea* (Aubl.) incorporated into cosmetic emulsion at 1 mg/mL and 10 mg/mL also demonstrated low SPF.[12] The crude extract and the ethanolic and hexane fractions from the leaf of *Ephedranthus pisocarpus* R.E.Fr in concentrations up to 100 mg/ml showed SPF of 3.0, 4.75, and 4.85, respectively.[13] The ethanolic extract of the leaf from *Cordia glabrata* (MART.) A.DC. at 200 µg/ml showed SPF ranging from 4.10 to 5.47. The variation of SPF was related to the stage of development of the leaf.[14]

Other hand, several plant species showed SPF above 6. The ethanolic extract at 100 mg/ml of the bark from *Schinopsis brasiliensis* Engl showed an SPF of 6.27.[15] The hydroethanolic extracts at 0.1 mg/ml of fifteen plant species from the northeast region demonstrated SPF above 6 in five species. *Erythrina velutina* showed the highest SPF of 9.71, *Amburana cearenses* of 7.61, *Spondias tuberosa* of 7.22, *Schinopsis brasiliensis* of 6.26, and *Anacardium occidentale* of 6.12. Correlation positive between SPF and concentrations of flavonoids and coumarins were found in *Erythrina velutina.*[16]

The hydroethanolic extracts at 10% of leaf, bark, or flowers from *Aniba canelilla, Brosimum acutifolium, Dalbergia monetaria, Aspidosperma nitidum, Arrabidaea chica*, and *Caesalpinia pyramidalis*, natives from the Brazilian Amazon basin incorporated into cosmetic formulations have their photoprotective activity assessed. Only the extract of *D. monetaria* showed an SFP of 6. The critical wavelength was 373 nm, and the ratio UVA/UVB of 0.441.

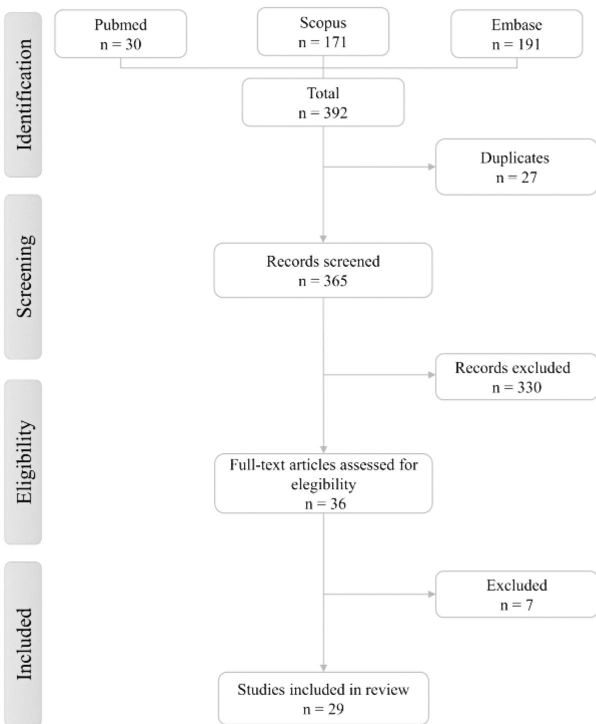

Figure 1: Flowchart of the study.

The critical wavelengths of *A. chica, A. canelilla, A. nitidum*, and *D. monetaria* were above 370 nm, which classifies these extracts in a broad spectrum of photoprotection, with the highest value in *A. chica* at 383 nm, followed by *A. canelilla* at 380 nm. The ratios of UVA/UVB were 0.695 and 0.586. The authors concluded that the hydroethanolic extract of *D. monetaria* has promising photoprotective activity and recommended complementary evaluation.[17]

The ethanolic extracts at 10% of leaves from *L. brasiliensis, L. rotundifolia, L. rubella*, and *L. sericea* incorporated into cosmetic preparation had their SPF estimated by spectral scanning, and only the extract of *L. sericea* showed a promising SPF of 7.6. The UVAPF was 2.97, the ratio SPF/UVAPF was 2.6 and the critical wavelength was 375 nm.[18] A clinical study with healthy volunteers (*n*=10) evaluated a cosmetic lotion with 10% of ethanolic extract of leaves from *L. sericea* applied to the skin at 2.0 mg/cm², followed by irradiation with simulated sunlight. The SPF was 7.5, which was similar to that found in the *in vitro* study.[18]

The organic or inorganic filters modify the SPF of plant extracts as can be seen in Table 2 which summarizes the SPF of several plant extracts alone and combined with different filters. For instance, the ethanolic extract of leaf from *Marcetia taxifolia* at 125 and 250 µg/µl showed SPF of 8.35 and 15.52. In concentrations above 15 mg/ml, the SPF raised to thirty. Polowax lotion, a base formulation combined with 20% and 30% of the ethanolic extract of the plant presented SPF of 42.55 and 43.11, which was superior to the control, a sunscreen with 3-benzophenone at 5% and an SPF of 39.8.[19]

The methanolic, aqueous, and hydroalcoholic extracts at 0.25 mg/ml of moss species *Leucobryum* sp. presented SPF of 17.57, 9.28, and 12.00. The combination of each extract with 3-benzophenone at 50 µg/ml, increased the SPF, with the highest value of 38.38 for the hydroalcoholic extract of moss.[20] Hydroalcoholic extract at 10% of fruits from *Pterodon emarginatus* showed an SPF of 14.72, which increased to 24.77 after the addition of octyl methoxycinnamate at 0.1%.[21]

The ethanolic extracts of the genus Campomanesia as *C. guazumifolia, C. sessiliflora, C. xanthocarpa*, and *C. adamantium*, in concentrations from 2 to 8% presented SPF below 6. The combination of extracts has a low impact on the SPF. However, incorporating the ethanolic extracts at 4% of *C. xanthocarpa* and *C. adamantium* into a sunscreen formulation with octyl methoxycinnamate at 8% raised the SPF to 19.63.[22]

The ethanolic extract at 7.5% of *Psidium guajava* L. showed an SPF of 1 and the addition of 2-ethyl-hexyl methoxycinnamate at 7.5% raised the SPF to 18.9.[23] The hydroethanolic extracts at 10% of native species of Bamboo incorporated into cosmetic formulations presented an SPF below 6 in all species evaluated. The addition of avobenzone at 3%, octyl dimethyl para-aminobenzoic acid at 8%, and octyl methoxycinnamate at 7.5% to the hydroethanolic extracts of *Aulonemia aristulata, Chusquea meyeriana,* and *Merostachys pluriflora* raised the SPF to 86.15, 84.37, and 83.19. Studies of the stability of these formulations revealed a significant reduction in SPF after UV radiation, but the critical wavelength was above 370 nm and an SPF above 15.[24]

A study compared the SPF of formulations of the hydroalcoholic or aqueous/acetone extracts of *Bauhinia microstachya* var. *massambabensis* Vaz at 1% with formulations at the same concentration of the extracts with 3-benzophenone at 5%, octyl methoxycinnamate at 5%, and octocrylene at 5%. The extracts formulations showed SPF of 0.68 and 0.70, and the organic filters of seventeen. The association of the plant extracts with organic filters showed SPF of 17.8 and 16.9. The formulations were tested on the skin of ten healthy volunteers, at 2 mg/cm². Those with organic filters showed an SPF of 13.38, the aqueous/acetone extract with organic filters of 17.9, and the ethanolic extract with organic filters of 18.9. The authors attributed the increase in SPF to the antioxidant property of the plant extracts.[25]

The hydroalcoholic extract at 5% of bark from *Hymenaea martiana* Hayne showed an SPF of 12.91, which was lower than the control of 3-benzophenone at 5% of 15.46.[26] The mixture of the crude extract of the bark plant at 5% with 3-benzophenone at 5% increased the SPF to 23.26. Formulation with the bark extract has significant antioxidant activity, contrasting with 3-benzophenone.[26]

Table 1: Photoprotective activity of plant species from Brazil.

Species	Botanical family	Part	Plant extract	Results	Method	Reference
Acrocomia aculeata (Jacq.) Lodd. Ex. Martius.	Arecaceae	Nut	Plant oil 4%	1.1*	Diffuse transmittance	[36]
		Fruit	Plant oil 4%	4.3*	Diffuse transmittance	
Alternanthera brasiliana (L.) KUNTZE	Amaranthaceae	Aerial part	Hydroethanolic 4%	19.57*	Spectral scanning	[28]
Amburana cearenses (Allemão) A.C. Sm.	Fabaceae	Bark	Hydroethanolic 0.100 mg/ml	7.61*	Spectral scanning	[16]
Anacardium occidentale L.	Anacardiaceae	Bark	Hydroethanolic 0.100 mg/ml	6.12*	Spectral scanning	
Erythrina velutina Willd.	Fabaceae	Bark	Hydroethanolic 0.100 mg/ml	9.71*	Spectral scanning	
Schinopsis brasiliensis Engl.	Anacardiaceae	Bark	Hydroethanolic 0.100 mg/ml	6.26*	Spectral scanning	
Spondias tuberosa Arruda	Anacardiaceae	Bark	Hydroethanolic 0.100 mg/ml	7.22*	Spectral scanning	
Arrabidaea chica (Humb. and Bonpl.) B. Verlot	Bignoniaceae	Leaves	Hydroethanolic 52 µg/ml and chloroform 18 µg/ml	Increased cell viability Decrease free radicals in cells	UV-irradiated cells	[33]
Arrabidaea chica (Humb. and Bonpl.) B. Verlot	Bignoniaceae	Leaves	Hydroethanolic 10%	5* λ_C 383 nm UVA/UVB 0.695	Diffuse transmittance	[17]
Aspidosperma nitidum (Benth)	Apocynaceae	Bark	Hydroethanolic 10%	3*	Diffuse transmittance	
Aniba canelilla (H.B.K.) Mez.	Lauraceae	Bark	Hydroethanolic 10%	3* λ_C 380 nm UVA/UVB 0.586	Diffuse transmittance	
Brosimum acutifolium Huber	Moraceae	Bark	Hydroethanolic 10%	3*	Diffuse transmittance	
Caesalpinia pyramidalis Tul.	Leguminosae-papilionoideae	Flower	Hydroethanolic 10%	5*	Diffuse transmittance	[17]
Dalbergia monetaria L. f.	Leguminosae-papilionoideae	Bark	Hydroethanolic 10%	6* λ_C 373 nm UVA/UVB 0.441	Diffuse transmittance	
Bauhinia microstachya var. massambabensis Vaz	Fabaceae	Leaves	Acetone/water 1%	0.7*	Diffuse transmittance	[25]
			Ethanolic 1%	0.68*	Diffuse transmittance	

Campomanesia adamantium (Cambess.) O.Berg.	Myrtaceae	Leaves	Ethanolic 8%	4.74*	Spectral scanning	[22]
Campomanesia guazumifolia (Cambess.) O.Berg.			Ethanolic 8%	3*	Spectral scanning	
Campomanesia sessiliflora O.Berg.			Ethanolic 8%	2.6*	Spectral scanning	
Campomanesia xanthocarpa O.Berg.			Ethanolic 8%	5.5*	Spectral scanning	
Cecropia obtuse Trécul	Urticaceae	Leaves	Ethanolic 1.5 to 20 µg/ml	Reduced lipid peroxidation Increased cellular antioxidant	UV-irradiated cells	[35]
Aulonemia aristulata (Döll) McClure	Poaceae	Culms and leaves	Hydroethanolic **	-	Diffuse transmittance	[24]
Chusquea capituliflora Trin. *var. pubescens* McClure	Poaceae	Culms and leaves	Hydroethanolic **	-	Diffuse transmittance	[24]
Chusquea meyeriana Rupr.			Hydroethanolic **	-	Diffuse transmittance	
Merostachys pluriflora Munro ex E.G.			Hydroethanolic **	-	Diffuse transmittance	
Cocos nucifera Linn.	Arecaceae	Bark	Ethanolic 20%	16.5*	Spectral scanning	[27]
Cordia glabrata (MART.) A.DC.	Boraginaceae	Leaves	Ethanolic 200 µg/ml	5.4*	Spectral scanning	[14]
Ephedranthus pisocarpus R.E.Fr.	Annonaceae	Leaves	Ethanolic 100 mg/ml	3.0*	Spectral scanning	[13]
			Aqueous 100 mg/ml	4.7*	Spectral scanning	
			Hexane 100 mg/ml	4.8*	Spectral scanning	
Eugenia dysenterica Mart ex DC	Myrtaceae	Leaves	Hydroethanolic 40-150 µg/ml	Preserved cell viability	UV-irradiated cells	[35]
Euterpe oleracea Martius	Arecaceae	Fruit	Glycolic 5%	same SPF when combined with organic filters	Human clinical trials	[32]
Garcinia brasiliensis Mart.	Clusiaceae	Fruit peels	Ethanolic 20%	27.7* Increased cell viability	Cell viability	[6]
			Ethanolic 10%	Antioxidant activity Anti-inflammatory effect	Pre-clinical animal model study: UV irradiation	

Hymenaea martiana Hayne	Fabaceae	Bark	Hydroethanolic 5%	12.9*	Spectral scanning	[26]
Leucobryum sp.	Leucobryaceae	Moss	Methanolic 0.25 mg/ml	17.5*	Spectral scanning	[20]
Lippia brasiliensis (Link) T.R.S. Silva	Verbenaceae	Leaves	Ethanolic 10%	2.3*	Spectral scanning	[18]
Lippia rotundifolia Cham.			Ethanolic 10%	2.8*	Spectral scanning	
Lippia rubella (Moldenke) T.R.S.Silva and Salimena			Ethanolic10%	1.7*	Spectral scanning	
Lippia sericea Cham.			Ethanolic 10%	7.6* UVAPF 2.97 λ_C 375 nm SPF 7.5 (*in vivo*)	Diffuse transmittance Human clinical trials	
Marcetia taxifolia (A. St.-Hil.) DC.	Melastomataceae	Leaves	Ethanolic 30%	43.1*	Spectral scanning	[19]
Mauritia flexuosa L.f.	Lepidocaryeae	No data	Plant oil 100 µL/ml	Increased cell viability	UV-irradiated cells	[38]
Neoglaziovia variegata	Bromeliaceae	Leaves	Hydroethanolic1%	11.7*	Spectral scanning	[29]
Passiflora coccínea (Aubl.)	Passifloraceae	Leaves	Methanolic and glycolic 1 mg/ml and 10 mg/ml	Low SPF (data no showed)	Spectral scanning	[12]
Psidium guajava L.	Myrtaceae	Fruit	Ethanolic 7.5%	1*	spectral scanning	[24]
Pterodon emarginatus Vogel	Fabaceae	Fruit	Hydroethanolic 10%	14.7*	spectral scanning	[21]
Pterodon emarginatus Vogel	Fabaceae	Fruit	Plant oil 5 µg/ml	Reduced reactive NOS Anti-inflammatory effect	UV-irradiated cells	[37]
Schinopsis brasiliensis Engl	Anacardiaceae	Bark	Ethanolic 100 mg/ml	6.2*	spectral scanning	[16]
Spondias purpurea L.	Anacardiaceae	Bark	Hydroethanolic 10%	10.8*	spectral scanning	[30]
Spondias purpurea L.	Anacardiaceae	Fruit	Methanolic 50 mg/ml	43.7*	spectral scanning	[31]
Theobroma cacao L.	Malvaceae	Seed	Glycolic 1%	2.4*	spectral scanning	[11]

*SPF: Solar Protection Factor; UVAPF: UVA Protection Factor; λ_C: critical wavelengths; UVA/UVB: UVA/UVB Ratio; NOS: Nitrogen and Oxygen Species.**Data not demonstrated by authors.

The ethanolic extract of fibers from *Cocos nucifera* Linn. at 2 mg/ml and 5 mg/ml showed SPF of 10.48 and 14.09. Concentrations of 10 mg/ml and 20 mg/ml presented SPF of 12.37 and 11.50, which suggest a probable saturation in the absorption of UV radiation. A formulation with the extract at 20% showed an SPF of 16.54, which was like 3-benzophenone at 5% used as control.[27]

The hydroalcoholic extract at 5% of the aerial parts from *Alternanthera brasiliana* was incorporated into a gel formulation and submitted to several cycles of freezing. After 12 days, the SFP raised to 19.57, which was probably due to the degradation of the formulation, by hydrolysis of glycosylated flavonoids and liberation of the aglycone, which increased the SPF.[28]

A sunscreen formulation with 3-benzophenone at 7%, octyl methoxycinnamate at 5%, zinc oxide at 2%, and titanium dioxide at 3%, showed an SPF of 12.95, and the addition of hydroalcoholic extract at 1% of leaf from *Neoglaziovia variegata* increased to 14.93, which was higher than the extract alone of 11.75.[29]

Other studies demonstrated no significant influence on SPF when natural products were associated with organic or inorganic filters. For example, the hydroalcoholic extract at 10% of bark from *Spondias purpurea* L. showed an SPF of 10.84, while octyl methoxycinnamate at 7.5% of 17.16. The incorporation of the bark extract to octyl methoxycinnamate at the same concentrations reduced the SPF to 15.87.[30] Moreover, only the methanolic extract at 50 mg/ml of fruits from *Spondias purpurea* L. presented an SPF of 43.78.[31] The glycolic extract of fruits from *Euterpe oleracea* at 5% incorporated into a formulation with synthetic organic filters and evaluated on the skin of human volunteers (*n*=10) presented an SPF of 25.3, which was like the formulation with synthetic filters with 3-benzophenone at 2.5%, octocrylene at 1% and 2-ethyl hexyl methoxycinnamate at 5%.[32]

The protective effect of plant extracts on the oxidative damage caused by solar radiation was evaluated in the different skin cells. The hydroethanolic at 52g/ml and the chloroform fractions at 18 µg/mL of leaf from *Arrabidaea chica* tested in L929 murine fibroblasts previously exposed to UVA and UVB radiations demonstrated a significant reduction in cell viability and an increase in the generation of reactive species of oxygen and nitrogen (NOS) in the no treated cells, which was most evident in cells exposed to UVA radiation. Moreover, the post-treatment of irradiated cells with the extracts decreased the formation of anion superoxide in mitochondria and the cellular lipid peroxidation.[33]

The hydroalcoholic extract of leaf from *Eugenia dysenterica* DC in HFF-1 fibroblasts previously exposed to the plant extract followed by UVA radiation revealed a photoprotective activity in low concentrations (40-150 µg/ml) but in high concentrations (200-300 µg/ml) the extract was phototoxic.[34] The prevention of oxidative stress of ethanolic extract of leaf from *Cecropia obtusa* at concentrations of 1.5 to 20 µg/ml was demonstrated in HaCaT cells exposed to the extract and, subsequently, UVA radiation. There was a significant reduction in the levels of malondialdehyde and maintenance of levels of reduced glutathione and activities of catalase and superoxide dismutase in cells exposed to the extract.[35]

The photoprotective and antioxidant activities of the ethanolic extract of epicarp from *Garcinia brasiliensis* at concentrations of 50 and 100 mg/ml were tested in pre-treated L929 murine fibroblast exposed to UVB radiation. The cell viability increased by 16.3 and 20.1% when compared to the non-treated cells. The SPF were 15.9 and 18.5. The photoprotective activity

Table 2: Solar Protection Factor (SPF) of Brazilian natural products alone or with synthetic filters.

Natural product			Synthetic filter			Combined SPF	Method	Reference
	Content	SPF		Content	SPF			
Ethanolic extract of *Psidium guajava* L	7.5%	1	2-ethyl-hexyl methoxycinnamate	7.5%	8.1	18.9	Spectral scanning	[24]
Ethanolic extracts of *Campomanesia xanthocarpa* + Ethanolic extracts of *Campomanesia adamantium*	4% + 4%	< 6	Octyl methoxycinnamate	8%	17.56	19.63	Spectral scanning	[22]
Glycolic extract of *Euterpe oleracea* at 5%	5%	#	3-benzophenone + Octocrylene + 2-ethylhexyl methoxycinnamate	2.5% + 1% + 5%	22.5	25.3	Human clinical trials	[32]
Hydroalcoholic extract *Neoglaziovia variegata*	1%	11.75	3-benzophenone + octyl methoxycinnamate + zinc oxide + titanium dioxide	7% + 5% + 2% + 3%	12.65	14.93	Spectral scanning	[29]
Hydroalcoholic extract of *Hymenaea martiana*	5%	12.91	3-benzophenone	5%	15.46	23.26	Spectral scanning	[26]

Hydroalcoholic extract of *Pterodon emarginatus*	10%	14.72	Octyl methoxycinnamate	0.1%	8.75	24.77	Spectral scanning	[37]
Hydroalcoholic extract of *Spondias purpurea* L.	10%	10.84	Octyl methoxycinnamate	7,5%	17.16	15.87	Spectral scanning	[30]
Natural product			**Synthetic filter**			**Combined SPF**	**Method**	**Reference**
	Content	SPF		Content	SPF			
Hydroalcoholic extracts of *Leucobryum* sp.	1 mg/mL	12.00	3-benzophenone	50 µg/mL	19.07	38.38	Spectral scanning	[20]
Hydroalcoholic extracts of *Bauhinia microstachya* var. massambabensis Vaz	1%	0.70	3-benzophenone + octylmethoxycinnamate + octocrylene	5% + 5% + 5%	17	17.8	Diffuse transmittance	[25]
*	*	#	*	*	13.38	18.98	Human clinical trials	[25]
Hydroethanolic extract of *Aulonemia aristulata*	10%	#	Avobenzone + octyldimethyl PABA + octyl methoxycinnamate	3% + 8% + 7,5%	#	86.15	Diffuse transmittance	[24]
Hydroethanolic extract of *Chusquea meyeriana*	10%	#	Avobenzone + octyldimethyl PABA + octyl methoxycinnamate	3% + 8% + 7,5%	#	84.37	Diffuse transmittance	[24]
Hydroethanolic extract of *Merostachys pluriflora*	10%	#	Avobenzone + octyldimethyl PABA + octyl methoxycinnamate	3% + 8% + 7,5%	#	83.19	Diffuse transmittance	[24]
Plant oil *Acrocomia aculeata* (Jacq.) Lodd. Ex. Martius.	4%	1.1	Octocrylene/Avobenzone 7:3	1%	14	27	Diffuse transmittance	[36]
Water/acetone extracts of *Bauhinia microstachya* var. massambabensis Vaz	1%	0.68	3-benzophenone + octylmethoxycinnamate + octocrylene	5% + 5% + 5%	17	17.8	Diffuse transmittance	[25]
*	*	#	*	*	13.38	17.90	Human clinical trials	[25]

#not determined *same plant extract.

was dose-dependent and associated with 7-epiclusianone, a benzophenone that constitutes up to 57% of the plant extract. A topical formulation at 10% of the ethanolic extract was applied in Wistar rats before exposure to UVB radiation (2,87 J/cm²). Tissues irradiated were removed and the levels of antioxidants were measured. The exposed group showed a reduction in the depletion of reduced glutathione, with values like the control group. Levels of myeloperoxidase were similar in both groups. In addition, there was a significant reduction in pro-inflammatory cytokines in the exposed group, with levels of IL-1B decreasing by 63% and TNF-α by 64%, which suggests a probable modulation of the oxidant and pro-inflammatory action of UVB radiation.[6]

The oil of nuts and fruits at 4% from *Acrocomia aculeata* (Jacq.) Lodd. Ex. Martius. showed SPF of 1.1 and 4.3. The nuts oil carried in nano lipid particles and incorporated into a sunscreen formulation having octocrylene at 0.7% and avobenzone at 0.3% has an SPF of 27.[36]

The antioxidant and anti-inflammatory activities of the nanoemulsion of *Pterodon emarginatus* oil, at 5 μg/ml and 10 μg/ml were tested in human keratinocytes exposed to UVA radiation. There were significant reductions in the generation of NOS and the levels of IL-6 e IL-8 at a concentration of 5 μg/mL, suggesting a potential influence of the nanoemulsion in the modulation of the inflammatory response.[37]

The viability of HaCaT and fibroblasts 3T3 cells was evaluated after irradiation to UVA/UVB or UVA and then exposure to the plant oil from *Mauritia flexuosa* at 100 μL/ml incorporated in formulations with surfactants and other active ingredients, such as Vitamin E and D-panthenol. The viability decreased in both cells before and after the radiation in formulations with plant oil, surfactants, Vitamin E and D-panthenol. The oil formulation increased the viability of HaCaT cells exposed to UVA/UVB radiation. Exposure to UVA reduced the viability of 3T3 cells in the formulation with the same surfactant, vitamin E, and plant oil. The addition of D-panthenol increased the cell viability, suggesting a synergic action with the oil, probably due to significant antioxidant activity related to the high content of carotenoids. Thus, the oil can be a potential carrier of other photoprotective compounds.[38]

Overall, these data demonstrate the low number of studies evaluating the photoprotective activity of plants in Brazil, a tropical country with a high incidence annual of solar radiation and considerable biodiversity. Moreover, the lack of studies with healthy volunteers and the availability of a sunscreen formulation with the benefic effects of these plants are relevant issues, especially in a country where skin cancer is an important public health problem. Thus, these data recommend building public-private partnerships for the research and development of sunscreens formulations with promising plant extracts found in these preliminary studies.

CONCLUSION

The studies that evaluated the photoprotective activity of plants in Brazil demonstrates that some species presented interesting solar protection factor *in vitro*, such as *Erythrina velutina*, *Dalbergia monetaria*, and *Garcinia brasiliensis*, which are potential candidates for complementary studies to validate their uses in sunscreens formulations. The antioxidant and anti-inflammatory activities of *Garcinia brasiliensis* in fibroblasts also is a relevant issue for further investigation as they prevented the harmful effects of solar radiation on skin cells *in vitro*.

ACKNOWLEDGEMENT

The authors are grateful to Para Federal University that delivering access to the electronic databases.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

Author contribution

TPP, MTS, MAA, NRBR, and JLFV contributed equally to the manuscript in the design of the review, selection of databases, interpretation of the results, draft manuscript, and approval a version final for submission.

REFERENCES

1. Balogh TS, Velasco MVR, Pedriali CA, Kaneko TM, Baby AR. Ultraviolet radiation protection: Current available resources in photoprotection. An Bras Dermatol. 2011;86(4):732-42. doi: 10.1590/s0365-05962011000400016, PMID 21987140.
2. Ministero da Saude-Brazil [Instituto nacional de câncer (INCA)]; 2020, May 05. Estimativa 2020. [retrieved Feb 10, 2022 from]. Available from: https://www.inca.gov.br/estimativa/estado-capital/brasil.
3. Saewan N, Jimtaisong A. Natural products as photoprotection. J Cosmet Dermatol. 2015;14(1):47-63. DOI: 10.1111/jocd.12123, PMID 25582033.
4. Nascimento CS, Nunes LCC, Lima AD, Júnior SG, Rolim P. Incremento do FPS em formulação de protetor solarutilizando extratos de própolis verde e vermelha. Rev Bras Farm. 2009;30:334-9.
5. Violante IMP, Souza IM, Venturini CL, Ramalho AFS, Santos RAN, Ferrari M. Avaliação *in vitro* da atividade fotoprotetora de extratos vegetais do cerrado de Mato Grosso. Rev Bras Farmacogn. 2009;19(2a):452-57. doi: 10.1590/S0102-695X2009000300020.
6. Figueiredo SA, Vilela FMP, Da Silva CA, Cunha TM, Dos Santos MH, Fonseca MJV. *In vitro* and *in vivo* photoprotective/photochemopreventive potential of *Garcinia brasiliensis* epicarp extract. J Photochem Photobiol B. 2014;131:65-73. doi: 10.1016/j.jphotobiol.2014.01.004, PMID 24491421.
7. Bolzani VdS, Valli M, Pivatto M, Viegas C. Natural products from Brazilian biodiversity as a source of new models for medicinal chemistry. Pure Appl Chem. 2012;84(9):1837-46. doi: 10.1351/PAC-CON-12-01-11.
8. Valli M, Russo HM, Bolzani VdS. The potential contribution of the natural products from Brazilian biodiversity to bioeconomy.An Acad Bras Cienc. 2018;90(1);Suppl 1:763-78. doi: 10.1590/0001-3765201820170653, PMID 29668803.
9. Brasil é o quarto maior mercado de beleza e cuidados pessoais do mundo. Forbes. 2020, July 04.
10. Ministério da Saude/Agência Nacional de Vigilância Sanitária – RDC nº 30. Ministério da Saúde, Agência Nacional de Vigilância Sanitária; 2012, June 01 [retrieved Feb 20, 2022 from]. Available from: https://bvsms.saude.gov.br/bvs/saudelegis/anvisa/2012/rdc0030_01_06_2012.html.
11. Garcia LB, Pires GA, Oliveira DAJ, Silva LAO, Gomes AF, Amaral JG, *et al*. Incorporation of glycolic extract of cocoa beans (*Theobroma cacao* L.) into microemulsions and emulgels for skincare. Ind Crops Prod. 2021;161:113181. doi: 10.1016/j.indcrop.2020.113181.
12. Silva GCd, Salvador MJ, Bottoli CBG. Towards the cosmetic application of *Passiflora coccinea* (Aubl.): Antioxidant activity and photoprotective capacity of the methanolic and glycolic leaf extracts.Braz J Pharm Sci. 2020;56. doi: 10.1590/s2175-97902019000317691.
13. Santos LKB, Veras MDA, Marques KKG, DE Moraes Alves MM, Mendes AN, DE Amorim Carvalho FA, et al. Assessment of *in vitro* Anti-melanoma potential of *Ephedranthus pisocarpus* R.E.Fr. Anticancer Res. 2020;40(9):5015-24. doi: 10.21873/anticanres.14504, PMID 32878789.
14. Debiasi BW, Raiser AL, Dourado SHA, Torres M Andrighetti CR, *et al*. Phytochemical screening of *Cordia glabrata* (MART.) A. DC. extracts and their potential antioxidant, photoprotective, antimicrobial, and antiviral activities.Braz J Biol. 2021;83.
15. Lima-Saraiva SRGD, Oliveira FGDS, Junior RGDO, Araújo CDS, Oliveira APD, Pacheco AGM, *et al*. Chemical analysis and evaluation of antioxidant, antimicrobial, and photoprotective activities of *Schinopsis brasiliensis* Engl. (Anacardiaceae). Sci World J. 2017;2017. doi: 10.1155/2017/1713921.

16. Andrade BA, Chernichiarro Corrêa A, Soares Gomes A, Da Silva Neri P, Peixoto Sobrinho TdS, de Sousa Araújo T, *et al*. Photoprotective activity of medicinal plants from the caatinga used as anti-inflammatories.Phcogmag. 2019;15(61):356. doi: 10.4103/pm.pm_482_18.
17. Martins FJ, Caneschi CA, Vieira JL, Barbosa W, Raposo NR. Antioxidant activity and potential photoprotective from amazon native flora extracts. J Photochem Photobiol B. 2016;161:34-9. doi: 10.1016/j.jphotobiol.2016.05.012, PMID 27208744.
18. Polonini HC, Brandão MAF, Raposo NRB. A natural broad-spectrum sunscreen formulated from the dried extract of Brazilian *Lippia sericea* as a single UV filter.RSC Adv. 2014;4(107):62566-75. doi: 10.1039/C4RA11577E.
19. Costa SCC, Detoni CB, Branco CRC, Botura MB, Branco A. *In vitro* photoprotective effects of *Marcetia taxifolia* ethanolic extract and its potential for sunscreen formulations.Rev Bras Farmacognosia. 2015;25(4):413-8. doi: 10.1016/j.bjp.2015.07.013.
20. Fernandes AS, Mazzei JL, Evangelista H, Marques MRC, Ferraz ERA, Felzenszwalb I. Protection against UV-induced oxidative stress and DNA damage by Amazon moss extracts.J Photochem Photobiol B. 2018;183:331-41. doi: 10.1016/j.jphotobiol.2018.04.038, PMID 29758545.
21. Rocha de Carvalho W, Ceres Moreira L, Valadares M, A. Diniz D, Freitas Bara M. Pterodon emarginatus hydroalcoholic extract: Antioxidant and photoprotective activities, noncytotoxic effect, and perspective of obtaining formulations with photochemoprotective activity. Phcogmag. 2019;15(64):176. doi: 10.4103/pm.pm_580_18.
22. Catelan TBS, Gaiola L, Duarte BF, Cardoso CAL. Evaluation of the *in vitro* photoprotective potential of ethanolic extracts of four species of the genus Campomanesia.J Photochem Photobiol B. 2019;197:111500. doi: 10.1016/j.jphotobiol.2019.04.009, PMID 31200215.
23. Mota MD, Costa RYS, Guedes AaS, Silva LCRCe, Chinalia FA. Guava-fruit extract can improve the UV-protection efficiency of synthetic filters in sun cream formulations.J Photochem Photobiol B Biol. 2019;201:111639. doi: 10.1016/j.jphotobiol.2019.111639.
24. Wróblewska KB, Baby AR, Grombone Guaratini MTG, Moreno PRH. *In vitro* antioxidant and photoprotective activity of five native Brazilian bamboo species. Ind Crops Prod. 2019;130:208-15. doi: 10.1016/j.indcrop.2018.12.081.
25. Reis Mansur MCPP, Leitão SG, Cerqueira-Coutinho C, Vermelho AB, Silva RS, Presgrave OAF, *et al. In vitro* and *in vivo* evaluation of efficacy and safety of photoprotective formulations containing antioxidant extracts. Rev Bras Farmacognosia. 2016;26(2):251-8. doi: 10.1016/j.bjp.2015.11.006.
26. Oliveira FGdS, Veras BOd, Silva APSd, Araújo ADd, Barbosa DCdS, Silva TdCM, *et al*. Photoprotective activity and HPLC-MS-ESI-IT profile of flavonoids from the barks of *Hymenaea martiana* Hayne (Fabaceae): Development of topical formulations containing the hydroalcoholic extract. Biotechnol Biotechnol Equip. 2021;35(1):504-16. doi: 10.1080/13102818.2021.1901607.
27. Oliveira MBS, Valentim IB, Santos TR, Xavier JA, Ferro JNS, Barreto EO, *et al*. Photoprotective and antiglycation activities of non-toxic *Cocos nucifera* Linn. (Arecaceae) husk fiber ethanol extract and its phenol chemical composition. Ind Crops Prod. 2021;162:113246. doi: 10.1016/j.indcrop.2021.113246.
28. Alencar Filho JMTd, Sampaio PA, De Carvalho ISd, Guimarães AL, Amariz IAe, Pereira ECV, *et al*. Flavonoid enriched extract of *Alternanthera brasiliana* with photoprotective effect: Formulation development and evaluation of quality.Ind Crops Prod. 2020;149:112371. doi: 10.1016/j.indcrop.2020.112371.
29. Oliveira-Júnior RGD, Souza GR, Ferraz CAA, Oliveira APD, Araújo CDS, Lima-Saraiva SRGD, et al. Development and evaluation of photoprotective O/W emulsions containing hydroalcoholic extract of *Neoglaziovia variegata* (Bromeliaceae). Sci World J. 2017;2017: 5019458. doi: 10.1155/2017/5019458. PMID: 28680948.
30. Rodrigues FAM, Giffony PS, Dos Santos SB, Guedes JA, Ribeiro MEN, De Araújo TGD, et al. *Spondias purpurea* L. stem bark extract: Antioxidant and *in vitro* photoprotective activities.J Braz Chem Soc. 2021;32:1918-30. doi: 10.21577/0103-5053.20210082.
31. Silva RV, Costa SCC, Branco CRC, Branco A. *In vitro* photoprotective activity of the *Spondias purpurea* L. peel crude extract and its incorporation in a pharmaceutical formulation.Ind Crops Prod. 2016;83:509-14. doi: 10.1016/j.indcrop.2015.12.077.
32. Daher CC, Fontes IS, Rodrigues RdO, Damasceno GAdB, Soares DdS, Aragão CFS, et al. Development of O/W emulsions containing *Euterpe oleracea* extract and evaluation of photoprotective efficacy. Braz J Pharm Sci. 2014;50(3):639-52. doi: 10.1590/S1984-82502014000300024.
33. Ribeiro FM, Volpato H, Lazarin-Bidóia D, Desoti VC, De Souza RO, Fonseca MJV, *et al*. The extended production of UV-induced reactive oxygen species in L929 fibroblasts is attenuated by posttreatment with *Arrabidaea chica* through scavenging mechanisms. J Photochem Photobiol B. 2018;178:175-81. doi: 10.1016/j.jphotobiol.2017.11.002, PMID 29156345.
34. Moreira LC, de Ávila RI, Veloso DFMC, Pedrosa TN, Lima ES, do Couto RO, *et al. In vitro* safety and efficacy evaluations of a complex botanical mixture of *Eugenia dysenterica* DC. (Myrtaceae): Prospects for developing a new dermocosmetic product. Toxicol *in vitro*. 2017;45(3):397-408. doi: 10.1016/j.tiv.2017.04.002, PMID 28389280.
35. Alves GdAD, De Souza RO, Rogez H, Masaki H, Fonseca MJV. *Cecropia obtusa*, an Amazonian ethanolic extract, exhibits photochemoprotective effect *in vitro* and balances the redox cellular state in response to UV radiation. Ind Crops Prod. 2016;94:893-902. doi: 10.1016/j.indcrop.2016.09.064.
36. Dario MF, Oliveira FF, Marins DSS, Baby AR, Velasco MVR, Löbenberg R, *et al*. Synergistic photoprotective activity of nanocarrier containing oil of *Acrocomia aculeata* (Jacq.) Lodd. Ex. *Martius - Arecaceae*. Ind Crops Prod. 2018;112:305-12. doi: 10.1016/j.indcrop.2017.12.021.
37. Pacheco MT, Silva ACG, Nascimento TL, Diniz DGA, Valadares MC, Lima EM. Protective effect of sucupira oil nanoemulsion against oxidative stress in UVA-irradiated HaCaT cells.J Pharm Pharmacol. 2019;71(10):1532-43. doi: 10.1111/jphp.13148, PMID 31378977.
38. Zanatta CF, Mitjans M, Urgatondo V, Rocha-Filho PA, Vinardell MP. Photoprotective potential of emulsions formulated with Buriti oil (*Mauritia flexuosa*) against UV irradiation on keratinocytes and fibroblasts cell lines.Food Chem Toxicol. 2010;48(1):70-5. doi: 10.1016/j.fct.2009.09.017, PMID 19766688.

Cite this article: Paixão TP, Silva MT, Andrade MA, Raposo NRB, Vieira JF. Plants from Brazil with Potential Photoprotective Activity: A Review. Pharmacog Rev. 2023;17(33):204-13.