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Original Research Article

Evaluation of the *α-amylase, α-glucosidase*, and tyrosinase inhibitory and photoprotective activities of organic solvent and aqueous Extracts of *Retama monosperma* stem

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ABSTRACT

Retama monosperma **is** a medicinal plant widely used in traditional medicine across the Mediterranean region to treat various conditions, including diabetes, rheumatism, hyperlipidemia, and hypertension. The present study aimed to investigate the enzyme (*α*-amylase, *α*-glucosidase, and tyrosinase) inhibitory activity as well as the photoprotective effect of the extracts of *R. monosperma* stem. Organic solvent (hexane, ethyl acetate, and ethanol) extracts of *R. monosperma* stem were obtained by Soxhlet extraction, while aqueous extract was obtained by maceration. The *α*-amylase and *α*-glucosidase inhibitory activities of the extracts were investigated *in vitro* using the spectrophotometric method. Furthermore, the efficacy of the extracts as dermo-protective and photoprotective agents were evaluated by tyrosinase inhibitory activity and by ultraviolet absorbance test. The results showed that the hexane extract exhibited the highest *α*-amylase inhibitory activity (IC_{50} = 273.91 ± 0.61 µg/mL), for the *α*-glucosidase inhibitory activity, the aqueous extract demonstrated the highest potency (IC_{50} = 2331.12 ± 2.69 µg/mL). The aqueous extract showed the highest tyrosinase inhibitory activity (615.52 ± 2.54 µg QE/mg extract). Additionally, the 10 mg/mL aqueous extract displayed significant photoprotective activity, with high UVA (1.810 ± 0.031) and UVB (2.112 ± 0.008) absorbance values. The results of this study have highlighted the therapeutic potential of *R. monosperma*, and established a solid foundation for future research on natural therapies and the development of innovative drugs for the treatment of hyperglycemia and pigmentation disorders.

Keywords: *Retama monosperma*, Enzyme activity, *α*-amylase, *α*-glucosidase, Anti-tyrosinase, Ultraviolet absorbance.

Introduction

Plants are abundant sources of secondary metabolites, which exhibit various biological activities. These compounds are utilized as medicines for the treatment of diseases. Plant-derived molecules are regarded as effective, efficacious, and safe with minimal side effects due to their natural origin.[1–3] In recent years, the use of medicinal plants in alternative medicine has witnessed a significant increase, especially in developed countries.[4] Medicinal plants have been used in healthcare for the treatment of diseases and as components of cosmetic formulations.[5–7] Furthermore, medicinal plants are extensively employed for disease prevention and the management of chronic conditions.[8–10] Due to their crucial catalytic role in numerous physiological processes, enzymes are key targets for drug intervention in human diseases, as modulating enzyme activity produces immediate and specific effects.[11,12] Inhibition of *α*-amylase and *α*-glucosidase enzymes, which are responsible for carbohydrate digestion and glucose absorption, respectively, leads to a reduction in postprandial hyperglycemia. This is crucial for the treatment of diabetes mellitus and the prevention of diabetic complications.[13,14] Tyrosinase is the key enzyme in the biosynthesis of melanin, which primarily serves a photoprotective function in human skin. Excessive melanin accumulation can lead to skin hyperpigmentation, hence, inhibiting tyrosinase activity is an interesting approach to regulating melanogenesis.[15]

Retama (Fabaceae) is a genus comprising four species. Locally known as "R'tem" in Morocco, this shrub features deciduous leaves and photosynthetic cladodes, which provide it with a unique adaptation to arid conditions.[16,17] In traditional medicine, these plants are used to treat various ailments and are particularly rich in secondary metabolites, such as flavonoids, essential oils, and alkaloids. Pharmacological research has demonstrated that *Retama* extracts possess antioxidant, antibacterial, antifungal, anti-inflammatory, and hypoglycemic properties, highlighting their considerable therapeutic potential.[18]

Retama monosperma (L.) Boiss is widely used in traditional medicine across the Mediterranean region to treat various conditions, including diabetes, rheumatism, hyperlipidemia, and hypertension.[19] It is also valued for its purgative, vermifuge, antiseptic, wound-healing, sedative, and abortifacient properties.[16,20] Although research on the phytochemical composition of *R. monosperma* is limited, pharmacological studies have shown that its extracts exhibit biological activities such as antioxidant,[21] anti-inflammatory,[22] anticancer,[23] antifungal effects,[24] and analgesic activity.[8] These effects are attributed to the presence of bioactive compounds, including alkaloids,[25] terpenes,[26] fatty acids,[27] steroids,[28] and flavonoids.[22]

However, to the best of our knowledge, there is no comprehensive study on the enzyme inhibitory potential of *R. monosperma*. Hence, the present study focused on investigating the *α*-glucosidase, *α*-amylase, and tyrosinase inhibitory activity and the photoprotective activity of fractions extracted from the cladodes of *R. monosperma*.

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This study aims to contribute to the understanding of the therapeutic properties of this plant.

Materials and Methods

Collection and identification of plant material

Retama monosperma stems were collected in July 2021 from the Mehdia forest in Rabat-Salé-Kénitra region, Morocco (geographical coordinates: 34°12'43.7"N 6°41'30.8"W). The plant material was identified and authenticated by a botanist at the herbarium of the Botany Department, Scientific Institute of Rabat, Morocco. Herbarium specimen was prepared and deposited at the institute's herbarium under the voucher specimen number RAB113533. The stems were washed, air dried at room temperature, and pulverized into coarse powder and kept in an opaque glass jar away from light and moisture.

Extraction of plant material

Powdered plant material (50 g) was placed in a cotton cellulose cartridge and subjected to Soxhlet extraction using 400 mL each of hexane (Sigma-Aldrich), ethyl acetate (Solvachim), and ethanol (Biosmart) in a sequential order of increasing priority. The extraction was considered complete when the solvent in the siphon tube became clear, which was the case after 6 hours for hexane, and 8 hours each for ethyl acetate and ethanol. In addition, the remaining pomace was macerated with 1000 mL distilled water for 8 hours at room temperature in the dark. The extracts were filtered through Whatman filter paper, then the organic solvent filtrate was concentrated using a rotary evaporator at reduced pressure, with a bath temperature of 35 to 40°C and a rotating speed of 120 rpm. The aqueous extract was freeze-dried to produce a powder after being frozen at -80°C for 24 hours. All the resulting extracts were stored at 4°C until they were used.[29]

Determination of total phenolic, total flavonoid and total tannin contents

The total phenolic content (TPC), total flavonoid content (TFC), and total tannin content (TTC) of the extracts of the stem of *R. monosperma* were determined according to a previously described procedure.[29]

Determination of the inhibitory potential on digestive enzyme activity

α-Amylase inhibition assay

The *α*-amylase inhibition assay of the four extracts was performed according to the procedure described by Dabiré *et al*. (2022).[30] A 250 µL volume of different concentrations of the extracts and 250 µL of *α*-amylase enzyme (60 U/mL)) (Sigma-Aldrich) prepared in phosphate buffer (0.02 M, pH 6.9) were incubated for 20 minutes at 37°C. After adding 250 µL of starch (Sigma-Aldrich) solution (2.5 mg/mL) to the reaction mixture, it was incubated for an additional 15 minutes at 37°C. One milliliter of dinitrosalicylic acid (DNS) (Sigma-Aldrich) reagent was added, and the mixture was heated at 95°C on a water bath for 10 minutes. Thereafter, the reaction mixture was diluted with 2 mL of distilled water. The absorbance of the reaction mixture was determined at 540 nm using a UV-Visible spectrophotometer (model: UV-1800APC, Laboratory Apparatus, China). Acarbose (Sigma-Aldrich) was used as the reference standard. The percentage inhibition of *α*-amylase activity was calculated using the formula below (Equation 1).

$$\%\ Inhibition = \frac{(Ac - Abc) - (Ae - Abe)}{(Ac - Abc)} \times 100 \qquad (1)$$

Where;
Ac: Absorbance of the negative control (enzyme and buffer)
Abc: Absorbance of the control blank (buffer without enzyme)
Ae: Absorbance of the sample (inhibitor and enzyme)
Abe: Absorbance of the sample blank (inhibitor without enzyme).

α-Glucosidase inhibition assay

The *α*-glucosidase inhibition assay was carried out according to the method described by Benrahou *et al*. (2022),[31] with minor adjustments. The procedure involved mixing 100 µL of 0.1 M phosphate buffer (pH 6.7) containing *α*-glucosidase enzyme (Sigma-Aldrich) of 0.1 U/mL with 150 µL of the sample or acarbose at a concentration (used as a reference standard) at different concentrations. The mixture was incubated at 37°C for 10 minutes. After incubation, the reaction mixture was supplemented with 200 µL of p-nitrophenyl-alpha-D-galactopyranoside (pNPG) solution (0.2 mM) (Sigma-Aldrich) made in 0.1 M sodium phosphate buffer (pH 6.7). The mixture was then incubated at 37°C for 30 minutes. After stopping the reaction with 1 mL of 0.1 M Na_2CO_3, the absorbance was measured at 405 nm using a UV-Visible spectrophotometer. The percentage inhibition of *α*-glucosidase was calculated using the formula below (Equation 2).

$$\%\ Inhibition = \frac{(Ac - Abc) - (Ae - Abe)}{(Ac - Abc)} \times 100 \qquad (2)$$

Where;
Ac: Absorbance of the negative control (enzyme and buffer)
Abc: Absorbance of the control blank (buffer without enzyme)
Ae: Absorbance of the sample (inhibitor and enzyme)
Abe: Absorbance of the sample blank (inhibitor without enzyme).

Determination of dermo-protective activity

Tyrosinase inhibition assay

The ability of the *R. monosperma* extracts to inhibit tyrosinase activity was evaluated following the protocol of Lee *et al*. (2011),[32] with slight modifications. The assay made use of 3,4-dihydroxyphenylalanine (L-DOPA) (Sigma-Aldrich), which is transformed into the reddish-brown chromophore dopachrome, which can be detected at 510 nm. A tyrosinase solution (330 U/mL) (Sigma-Aldrich) made in phosphate buffer (pH 6.5, 50 mM) was combined with 50 µL of each extract for each test. After a 10-minute incubation period at 37°C, 500 µL of L-DOPA substrate (5 mM) was added. The reaction mixture was further incubated at 37°C for 30 minutes. The absorbance of the resulting solution was measured at 510 nm using a UV-visible spectrophotometer (model: UV-1800APC, Laboratory Apparatus, China). Quercetin was used to construct the standard curve, and the results were expressed as micrograms of quercitrin equivalent per milligram of extract (µg QE/mg extract).

Ultraviolet Absorbance Test

The ultraviolet (UV) absorbance of the extracts of *R. monosperma* stem was measured using the procedure outlined by Lee *et al*. (2011),[32] and Zakhour *et al*. (2024).[33] To achieve final concentrations of 5 and 10 mg/mL, the extracts were dissolved in their corresponding extraction solvents. The absorbance of the solutions was measured for each sample at two distinct wavelengths: 300 nm for UVB rays and 365 nm for UVA rays. The outcomes were contrasted with reference standards of methyl salicylate (100 µg/mL) and 5% zinc oxide (ZnO).

Statistical Analysis

The experiments were conducted in triplicate and results were expressed as mean ± standard deviation (SD). Statistical analysis and mean comparisons were performed using one-way analysis of variance (ANOVA), followed by the Tukey test. Differences between mean values were considered statistically significant at $p < 0.05$. Data analysis was performed using GraphPad Prism 8. The Pearson correlation was employed to determine the relationship between the total phenolic, flavonoid, and tannin contents of *R. monosperma* extracts and their *α*-amylase, *α*-glucosidase, and tyrosinase inhibitory activities, as well as their absorbance values for UVA and UVB radiation.

Results and Discussion

Total phenolic, flavonoid and tannin contents

The total phenolic, flavonoid and tannin contents of *R. monosperma* stem extracts varied among the various extracts. The aqueous extract had the highest total phenolic content (236.31 ± 1.57 mg GAE/g extract), while the highest total flavonoid content (75.73 ± 0.05 mg QE/g extract) and the highest total tannin content (79.36 ± 0.59 mg CE/g extract) were found in the ethyl acetate and hexane extracts, respectively (Table 1).

Inhibitory potential on digestive enzyme activity

The hypoglycemic potential of the extracts of the stem of *R. monosperma* was assessed by evaluating their inhibition of *α*-amylase and *α*-glucosidase activities, and the result is summarized in Table 2.

All extracts tested showed concentration-dependent inhibitory effects against *α*-amylase and *α*-glucosidase, although their activity was lower

Table 1: Total phenolic, flavonoid and tannin contents of *R. monosperma* stem extracts

Parameter	Value			
	Hexane extract	**Ethyl acetate extract**	**Ethanol extract**	**Aqueous extract**
TPC (mg GAE/g extract)	47.11 ± 0.55	218.95 ± 0.22	212.75 ± 0.34	236.31 ± 1.57
TFC (mg QE/g extract)	21.98 ± 0.12	75.73 ± 0.05	26.38 ± 0.14	8.89 ± 0.44
TTC (mg CE/g extract)	79.36 ± 0.59	35.68 ± 0.96	7.14 ± 0.18	4.70 ± 0.15

Values are mean ± standard deviation (SD). **TPC**: Total phenolic content; **TFC**: Total flavonoid content; **TTC**: Total tannin content; **mg GAE/g extract**: milligram Gallic Acid Equivalent per gram of extract; **mg QE/g extract**: milligram Quercetin Equivalent per gram of extract; **mg CE/g extract**: milligram Catechin Equivalent per gram of extract.

Table 2: Alpha-amylase and Alpha-glucosidase inhibitory activities of *R. monosperma* stem extracts

Activity	IC_{50} Value (µg/mL)				
	Hexane extract	**Ethyl acetate extract**	**Ethanol extract**	**Aqueous extract**	**Acarbose**
***α*-amylase inhibition**	273.91 ± 0.61^{a}	2195.95 ± 9.25^{b}	4513.56 ± 5.85^{c}	578.02 ± 2.98^{d}	205.86 ± 2.99^{e}
***α*-glucosidase inhibition**	2357.81 ± 0.42^{a}	5033.76 ± 7.34^{b}	7853.24 ± 2.87^{c}	2331.12 ± 2.69^{a}	891.58 ± 15.41^{d}

Values are mean ± standard deviation (SD). Different superscript letters in the same row indicate significant difference ($p < 0.05$).

Table 3: Tyrosinase inhibitory activity of *R. monosperma* stem extracts.

Activity	Value (µg QE/mg extract)			
	Hexane extract	Ethyl acetate extract	Ethanol extract	Aqueous extract
Tyrosinase inhibition	493.07 ± 1.74^{a}	313.68 ± 0.88^{b}	405.66 ± 3.41^{c}	615.52 ± 2.54^{d}

Values are mean ± standard deviation (SD). µg QE/mg extract: microgram quercetin equivalent per mg extract. Different superscript letters in the same row indicate significant difference ($p < 0.05$).

Table 4: UVA and UVB radiation absorbance of *R. monosperma* stem extracts

Extract	Concentration	Absorbance	
		UVA	**UVB**
Hexane	**5 mg/mL**	1.036 ± 0.003^{a}	1.428 ± 0.003^{a}
	10 mg/mL	1.707 ± 0.002^{bcde}	1.950 ± 0.001^{a}
Ethyl acetate	**5 mg/mL**	1.149 ± 0.002^{a}	1.492 ± 0.001^{a}
	10 mg/mL	1.755 ± 0.015^{cbde}	1.936 ± 0.006^{a}
Ethanol	**5 mg/mL**	1.007 ± 0.002^{a}	1.219 ± 0.003^{a}
	10 mg/mL	1.774 ± 0.025^{dbce}	1.937 ±0.012^{a}
Aqueous	**5 mg/mL**	0.991 ± 0.001^{a}	1.396 ± 0.001^{a}
	10 mg/mL	1.810 ± 0.031^{ebcd}	2.112 ± 0.008^{a}
MS	**100 µg/Ml**	0.03 ± 0.010^{f}	2.23 ± 0.020^{a}
ZOX	**5 %**	2.33 ± 0.040^{g}	3.25 ± 0.020^{a}

Values are mean ± standard deviation (SD). Different superscript letters in the same column indicate a significant difference ($p < 0.05$). MS: Methyl salicylate, ZOX: Zinc oxide.

Table 5: Pearson's correlation coefficients among TPC, TFC, TTC, *α*-amylase, *α*-glucosidase, and tyrosinase inhibition and Absorbance values of UVA and UVB radiation.

TEST	TPC	TFC	TTC	*α*-amylase	*α*-glucosidase	Tyrosinase	UVA	UVB
TPC	1.0000							
TFC	0.2004	1.0000						
TTC	-0.9237	0.1502	1.0000					
***α*-amylase**	0.4639	0.2647	-0.5181	1.0000				
***α*-glucosidase**	0.4196	0.3314	-0.4513	0.9960	1.0000			
Tyrosinase	-0.0918	-0.8856	-0.1398	-0.5939	-0.6597	1.0000		
UVA	0.8909	-0.2466	-0.9485	0.2211	0.1476	0.3633	1.0000	
UVB	0.3660	-0.5910	-0.4604	-0.5026	-0.5734	0.8573	0.7056	1.0000

TPC: total phenolic content; **TFC**: total flavonoid content; **TTC**: total tannin content.

than that of the positive control, acarbose (IC_{50} values of 205.86 ± 2.99 µg/mL for *α*-amylase and 891.58 ± 15.41 µg/mL for *α*-glucosidase). The most significant activity was shown against *α*-amylase, where the hexane extract showed the highest potency, with an IC_{50} of 273.91 ± 0.61 µg/mL, followed by the aqueous extract (IC_{50} = 578.02 ± 2.98 µg/mL). The lowest activity against *α*-amylase was observed for the ethanol extract (IC_{50} = 4513.56 ± 5.85 µg/mL). For *α*-glucosidase, the aqueous extract showed the most promising activity, with an IC_{50} of 2331.12 ± 2.69 µg/mL, followed by the hexane fraction (IC_{50} = 2357.81 ± 0.42 µg/mL). The ethanol extract showed the lowest inhibition of *α*-glucosidase, with an IC_{50} of 7853.24 ± 2.87 µg/mL.

The enzymes *α*-amylase and *α*-glucosidase play a crucial role in carbohydrate digestion process. Alpha-amylase catalyzes the initial step in the break-down of complex carbohydrates, such as starch, into simple sugars. This step is essential for breaking down long polysaccharide chains into smaller units that are easier to absorb or convert by other enzymes. Alpha-glucosidase on the other hand, is involved in the final phase of carbohydrate digestion. It hydrolyzes disaccharides, such as maltose, into glucose, a form of sugar easily absorbed by the small intestine. Inhibition of *α*-glucosidase activity can slow down the conversion of disaccharides to glucose, thereby delaying glucose absorption in the digestive system. Simultaneous inhibition of *α*-amylase and *α*-glucosidase is a promising mechanism for managing postprandial hyperglycemia.[34,35] These inhibitors can help reduce post-meal glycemic spikes by slowing carbohydrate digestion and thus glucose absorption, leading to lower blood glucose levels.[36] This is particularly important for people suffering from diabetes, as insufficient insulin levels limit the body's ability to eliminate extracellular glucose. As a result, diabetics often have reduced levels of *α*-amylase to better regulate their blood sugar levels. In addition, *α*-amylase inhibitors are used by plants as a natural defense strategy against insects.[37]

The pharmacological properties of these enzyme inhibitors enable rapid reduction of elevated blood glucose levels in diabetic patients. However, the synthetic enzyme inhibitors currently in use are often associated with gastrointestinal side effects such as diarrhea, flatulence and abdominal bloating. Consequently, natural *α*-amylase and *α*-glucosidase inhibitors derived from edible plants are emerging as a promising alternative, offering comparable efficacy with reduced risks of side effects for the management of postprandial hyperglycemia.[38]

The ability of medicinal plants to reduce compounds, neutralize free radicals, donate hydrogen ions, and quench singlet oxygen are key criteria for assessing their antioxidant properties.[39] Research has shown that certain foods and medicinal plants contain powerful antioxidants that can help mitigate oxidative stress in conditions such as diabetes.[40] Phenols and flavonoids are natural compounds with anti-diabetic properties, which act by reducing oxidative stress, notably through the neutralization of free radicals. This process contributes to the inhibition of digestive enzymes, thus promoting the reduction of postprandial glucose levels.[41]

To this end, extensive research was carried out to investigate the inhibitory effects of the extracts of the stem of *R. monosperma* on the enzymes *α*-amylase and *α*-glucosidase. The results indicate that the most significant inhibitory effect was observed against *α*-amylase, suggesting a particularly effective interaction between the extracts tested and the key enzymes involved in carbohydrate digestion.

Different species of the same genus, *Retama*, have been previously studied for their antidiabetic properties. Flavonoids isolated from the aerial parts of *Retama raetam* have shown significant activity as *α*-glucosidase inhibitors.[42] Another *in vivo* study showed that the methanol extract of *Retama raetam* fruits possessed glucose-lowering properties in streptozotocin (STZ)-induced diabetic rats. An oral glucose tolerance test revealed that both doses (250 and 500 mg/kg) administered significantly decreased blood glucose levels after 30 and 60 minutes of glucose loading. Furthermore, daily administration of *Retama raetam* extract at a dose of 500 mg/kg for four consecutive weeks significantly increased blood glucose levels.[43]

According to results obtained by Moncef Chouaibi and collaborators, galactomannan extracted from *Retama raetam* seeds exhibited significant antidiabetic properties *in vivo*. It reduced blood glucose levels, increased serum insulin levels, inhibited digestive enzymes *α*-amylase and *α*-glucosidase, and has antioxidant properties.[44] Moreover, another study showed that administration of the aqueous extract of *Retama raetam* at a dose of 10 mg/kg notably decreased glucose levels in STZ-induced diabetic rats, along with an increase in serum insulin levels, indicating improved insulin function.[45]

Dermo-protective activity

Tyrosinase inhibitory activity

L-DOPA was used as a substrate to assess the effect of extracts of *R. monosperma* stem on tyrosinase inhibition. Results were expressed as µg QE/mg extract, using the quercitrin standard curve as a positive reference. As shown in Table 3, tyrosinase activity was significantly inhibited by the extracts tested, with the degree of inhibition varying according among the extracts.

The aqueous extract showed the highest inhibitory activity, with a value of 615.52 ± 2.54 µg QE/mg extract, followed by the hexane and ethanol extracts, with values of 493.07 ± 1.74 and 405.66 ± 3.41 µg QE/mg extract, respectively. The lowest inhibitory activity was observed in the ethyl acetate extract, with a value of 313.68 ± 0.88µg QE/mg extract.

Melanin acts beneficially to protect the skin from harmful UV rays. It also neutralizes free radicals and acts as a natural antioxidant and sunscreen.[46] However, overproduction of melanin in the skin can lead to the appearance of age spots, melasma, freckles, and various hyperpigmentation disorders.[47] Tyrosinase is recognized as a key target in the treatment of hyperpigmentation disorders, as it plays an essential role as an enzyme that regulates the rate of melanogenesis.[48] The oxidation of L-tyrosine to L-DOPA is catalyzed by tyrosinase, after which L-DOPA is oxidized to dopaquinone. Finally, tyrosinase induces dopaquinone synthesis, leading to melanin synthesis.[49] Tyrosinase, as a critical enzyme in melanin production, is the main enzyme responsible for the enzymatic browning of fruits and vegetables, which has a significant impact on their storage and processing.[50] For this reason, tyrosinase inhibitors are commonly used in a variety of fields, including cosmetic bleaching, fruit, and vegetable preservation and the treatment of certain diseases.[51] Numerous natural, semi-synthetic, and synthetic tyrosinase inhibitors have been identified by researchers. These inhibitors fall into several categories: flavonoids, chalcones, hydroquinones, stilbenes, kojic acid derivatives, benzaldehydes, coumarins, thiosemicarbazones, and azoles. Despite the identification of numerous tyrosinase inhibitors, only a few have been used clinically due to their side effects and low clinical efficacy.[52] It is therefore necessary to search for safer and more effective natural tyrosinase inhibitors from plants.

Ultraviolet absorbance

In this study, the UVA and UVB absorbance of extracts derived from *R. monosperma* stem was assessed at two concentrations (5 and 10 mg/mL). The results are presented in Table 4.

Excessive exposure to UVA and UVB rays can cause significant skin damage in humans, including skin aging and cancer. This method assesses a substance's ability to absorb UV radiation at specific wavelengths, thus determining its potential as a photoprotective agent.

Methyl salicylate at a concentration of 100 µg/mL and zinc oxide at a concentration of 5% were used as positive controls for UVB and UVA absorption, respectively. The results indicate that the extracts tested absorbed UVA and UVB radiation in a concentration-dependent manner. Among the extracts, the 10 mg/mL aqueous extract showed the most significant UV absorption, with an absorbance of 1.810 ± 0.031 for UVA and 2.112 ± 0.008 for UVB. Conversely, the 5 mg/mL aqueous extract showed the lowest absorbance for UVA (0.991 ± 0.001), while the 5 mg/mL ethanol extract showed an absorbance of 1.219 ± 0.003 for UVB. Although these results are promising, the UV absorption efficiency of the extracts remains lower than that of the reference standard sunscreen.

Exposure to solar UV radiation can have adverse effects on human skin, such as sunburn, premature aging, skin cancers, DNA damage, and localized immunosuppression.[53] Increasingly, botanical agents, which are substances derived from various plant parts such as stems, barks, and roots, are being recognized and preferred as an alternative to conventional synthetic UV filters. These substances are secondary metabolites produced by various plants, which play a crucial role in their growth and survival. Research indicates that these metabolites exhibit a wide range of biological activities, including antioxidant, antibacterial, and anti-inflammatory effects, as well as the ability to absorb UV radiation. Vitamin C, vitamin E, and plant extracts rich in phenolic compounds are among the most frequently mentioned botanical agents with these characteristics.[54] The absorption of UV rays by phenolic compounds is due to the presence of aromatic rings, which contain electronic resonances.[55] Indeed, UV filters designed to absorb UV radiation generally have aromatic rings and a carbonyl group in their molecular structure. These compounds capture UV photons, causing changes in their molecular configuration. The absorbed energy is then dissipated as heat or re-emitted as radiation at a higher wavelength.[55] In this context, extracts of *R. monosperma* stem were tested for their ability to absorb UV radiation (UVA and UVB).

Pearson's correlation coefficient

The Pearson correlation coefficient is a matrix used to measure the liner relationship between two variables. As presented in Table 5, a heat map illustrates the correlation coefficients between TPC, TFC, TTC, *α*-amylase, *α*-glucosidase, and tyrosinase inhibition and absorbance values of UVA and UVB radiation. Notably, a strong negative correlation (r = -0.9485) was observed between UVA absorption and TTC, indicating that higher TTC levels are associated with lower UVA absorption. Similarly, a strong negative correlation (r = -0.8856) was identified between TFC and tyrosinase inhibition, suggesting that higher TFC content is associated with lower tyrosinase inhibitory activity. Furthermore, the correlation between TPC and UVA absorption, with an r value of 0.8909, underscores the impact of TPC on the photoprotective activity.

Conclusion

In the current study, the capability of the extracts of *R. monosperma* stem to inhibit the enzymes *α*-amylase, *α*-glucosidase and tyrosinase was investigated, in addition to their ability to absorb ultraviolet rays (UVA and UVB). Regarding the sugar-digesting enzyme inhibition capacity, the hexane and aqueous extracts demonstrated significant ability to inhibit *α*-amylase and *α*-glucosidase enzymes. Moreover, the aqueous extract exhibited the highest UVB and UVA absorption capacity, and the strongest tyrosinase inhibitory activity. However, further experiments, including detailed phytochemical and pharmacological studies, are necessary to investigate broader therapeutic potential of *R. monosperma*.

Conflict of Interest

The authors declare no conflict of interest.

Authors' Declaration

The authors hereby declare that the work presented in this article is original and that any liability for claims relating to the content of this article will be borne by them.

Authors' contributions

FZB designed the study, conducted the statistical analysis, and drafted the manuscript.AM, HB, and AD contributed to the statistical analysis. AZ ensured the formal analysis and supervised the process. All authors read and approved the final manuscript.

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