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Phytochemical profiling and *in vitro* sun protection factor evaluation of *Phragmites australis*

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Excessive exposure to solar ultraviolet (UV) radiation is a major environmental factor contributing to skin damage, oxidative stress, photoaging, and increased risk of cancer. Although synthetic sunscreens are widely used, concerns regarding safety, ecological impact, and long-term side effects have prompted growing interest in natural, plant-derived photoprotective agents. This study investigates the phytochemical composition and sun-protective efficacy of *Phragmites australis*, a perennial grass known for its diverse secondary metabolites. Whole plants were collected, authenticated, and subjected to pharmacognostic evaluation, physicochemical analysis, and preliminary phytochemical screening. Extracts were prepared using water, chloroform, and ethanol through cold maceration. Microscopic examination revealed diagnostic features including calcium oxalate crystals, lignified vessels, and mucilage cells, while physicochemical parameters indicated moderate moisture content (9.4%), total ash (4.5%), and high water-soluble extractives (9.23%). Phytochemical screening confirmed the presence of flavonoids, phenols, tannins, saponins, and glycosides, compounds known for antioxidant and UV-absorbing properties. The sun protection factor (SPF) was determined spectrophotometrically using the Mansur equation. Among the extracts, ethanol exhibited the highest SPF value (11.025 ± 0.022), followed by chloroform (2.2699 ± 0.003) and aqueous (1.5338 ± 0.016). These findings highlight the potential of *Phragmites australis* ethanolic extract as a candidate for further development as a natural, plant-derived UV-protective agent, combining antioxidant activity with *in vitro* UV-absorbing capacity. The study provides novel insights into the dermatological potential of *Phragmites australis*; however, as SPF was determined solely by *in vitro* spectrophotometry, these findings should be regarded as preliminary.

Keywords: *Phragmites australis*, Sun protection factor, UV radiation, Mansur

INTRODUCTION

The skin protects against outside threats, but can be damaged by excessive exposure. Factors such as radiation, heavy metals, and pathogens affect the skin's protective system. In tropical countries like Indonesia, exposure to sunlight is constant, with temperatures reaching up to 50°C during summer. This heat can cause dehydration, dryness, and increased vulnerability to sunburn[1-4].

UV radiation, a component of sunlight, excites electrons in skin molecules from their lower energy state to a higher energy state, damaging skin defences and leading to tissue abnormalities. Sun exposure can cause burns, skin cancer, oxidative damage, erythema, inflammation, hyperpigmentation, wrinkle formation, and immunosuppression[5,6]. Solar UV radiation is categorized as UV-C (200–290 nm), UV-B (290–320 nm), and UV-A

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(320–400 nm)[7]. While UV-C is filtered by the atmosphere, UV-B penetrates the ozone layer and causes sunburn. UV-A reaches deeper epidermal and dermal layers, accelerating skin ageing. Several sunscreen formulations exist, including creams, gels, oils, lotions, moisturisers, ointments, and waxes. Although synthetic sunscreens provide broad protection and act quickly, they are often expensive and may cause adverse effects[8-11].

Recently, natural compounds from plants have been studied as sunscreen agents due to their UV absorption and antioxidant activities[12]. Herbal sunscreens are affordable, accessible, and generally safer. Antioxidants like vitamins, flavonoids, polyphenols, and carotenoids protect skin against UV damage. Key bioactive compounds include vitamins C and E, quercetin, lycopene, beta-carotene, resveratrol, and phenolic compounds. Physical blockers like titanium dioxide and zinc oxide are also widely used. The skin's natural sun protection includes lipids, proteins, and nucleotides. Research on herbal ingredients continues to expand due to their reduced skin irritation and fewer harmful effects compared to synthetic sunscreens. Sunscreen efficacy is typically expressed by the sun protection factor (SPF)[13-15]. SPF is defined as the ratio of UV energy required to produce minimal erythema dose (MED) on protected skin versus unprotected skin. Human volunteer phototesting measures sunscreen protection levels[16].

Sunscreens protect against sunburn and shield the skin from harmful UV-A and UV-B radiation, but natural active substances are preferred in skincare due to skin sensitivity, eco-friendliness, and fewer side effects. Natural substances also offer benefits like antioxidant, wound healing, antimicrobial, antibacterial, and dental therapeutic properties. Synthetic chemicals can cause skin discomfort and other health risks. Antioxidant capacity plays a significant role in sunscreen photoprotection[17-19].

Previous studies show *Amaranthus viridis* and *Solanum nigrum* contain high levels of flavonoids, particularly quercetin and rutin, exhibiting effective UV radiation blocking. Methanolic extracts were more potent than aqueous ones. Compared to *Solanum nigrum*, *Amaranthus viridis* extracts have higher flavonoid and phenolic content and greater UV protection[20].

Extracts from *Polyalthia longifolia* have demonstrated sun-protective properties. SPF values of bark extracts in ethanol, water, and chloroform were measured using UV spectrophotometry. Due to their flavonoid content, these extracts are widely used in skin cosmetics and suggested for enhancing SPF in sunscreen formulations[21].

Recent literature reinforces the photoprotective value of plant-derived antioxidants. A 2025 systematic review of curcumin, a polyphenolic compound from *Curcuma* species, found that it enhances sunscreen SPF through combined antioxidant, anti-inflammatory, and UV-absorbing mechanisms[22]. Likewise, a 2024 review of natural compounds in UV protection products highlighted that flavonoids, carotenoids, stilbenes, and phenolic acids absorb UV-A/UV-B radiation while offering antioxidant benefits comparable to synthetic filters, with fewer adverse effects[23]. A 2023 review of plant-derived natural UV filters similarly concluded that flavonoid- and polyphenol-rich extracts act through both UV absorption and free-radical scavenging, supporting their use in next-generation sunscreen formulations[24], while nanoparticle-based delivery of flavonoids has been shown to further enhance UVA photoprotection and reduce the toxicity concerns associated with conventional UV filters[25]. A 2024 review additionally emphasised that plant-derived photoprotective compounds offer a safer, more sustainable alternative to synthetic filters amid growing environmental and dermatological safety concerns, and natural compounds including flavonoids, tannins, and phenolic acids continue to be identified as promising sunscreen agents owing to their dual antioxidant and UV-absorbing activity[26]. These findings support the rationale for investigating flavonoid- and phenolic-rich species such as *Phragmites australis* as sustainable, plant-based photoprotective agents.

P. australis is a rhizomatous perennial reaching up to 6 m tall in aquatic or damp habitats. Its inflorescence ranges from green to purple-brown, and it is rich in flavonoid glycosides characteristic of the Poaceae family. It contains bioactive compounds such as benzoic acid, alpha-D-glucose, Aurantiamide acetate, beta-sitosterol, methyl gallate, palmitic acid, benzoic acid, p-coumaric acid, stigmasterol, vanillic acid, syringic acid, and lyoniresinol derivatives[27]. *P. australis* possesses pharmacological activities including anticancer, hepatic and renal protection, antibacterial, antiviral, anti-inflammatory, and skin protection. This study investigates the phytochemical profile and sun-protective effects of *P. australis* extracts obtained by cold maceration with water, chloroform, and ethanol[28].

P. australis was selected for this study due to its abundant phytochemical constituents and ethnomedicinal relevance. The plant is a natural source of flavonoids, phenolic acids, and tannins compounds known for their antioxidant activity and UV-absorbing capacity. Its traditional use in treating skin-related ailments supports its potential for dermatological applications. As a fast-growing and widely distributed wetland species, *P. australis* offers ecological sustainability and cost-effective extractability. The use of multiple solvents enables targeted isolation of bioactive compounds, allowing comparative evaluation of photoprotective efficacy[29].

Although the ecological, phytochemical, and pharmacological properties of *P. australis* have been documented in several contexts including its role in the phytoremediation of aquatic ecosystems, its traditional use as *Rhizoma phragmitis* in Chinese medicine, its broader phytochemical and biological profile across the genus *Phragmites*, and the antioxidant, antimicrobial, and anticancer activities of its nano-formulated leaf extracts

none of these reports has evaluated its sun-protective potential. To the best of our knowledge, this is the first study to determine the *in vitro* sun protection factor of *P. australis*, despite its well-documented flavonoid- and phenolic-rich profile, properties that are strongly associated with UV-absorbing and antioxidant activity in other plant species[30].

This study also differs from previously published reports on herbal sunscreen agents in several respects. Much of the existing literature has concentrated on already well-characterised botanicals, such as *Curcuma longa*, *Moringa oleifera*, and *Aloe vera*, formulated as finished creams, gels, or lotions and evaluated for SPF alone, often without corresponding pharmacognostic or physicochemical characterisation of the source plant material[30-31]. By contrast, the present investigation integrates macroscopic and microscopic pharmacognostic evaluation, physicochemical analysis, and qualitative phytochemical screening with a systematic, multi-solvent (aqueous, chloroform, and ethanol) comparison of photoprotective efficacy within a single study, allowing extract-specific phytoconstituent profiles to be directly correlated with the corresponding SPF values obtained via the Mansur equation. Furthermore, as a fast-growing, low-cost, and ecologically abundant wetland grass rather than a cultivated or commercially harvested botanical, *P. australis* offers a more sustainable and economically viable raw material than the sources typically investigated in prior herbal sunscreen research. Collectively, these distinctions establish the novelty of the present work and its contribution toward expanding the range of scientifically characterised, candidate plant-derived photoprotective agents, pending further formulation and *in vivo* evaluation. The study aims to statistically compare *in vitro* extract performance and contribute preliminary insights toward the development of plant-based photoprotective agents[31].

Materials and Methods

Materials

Whole plants of *P. australis* were gathered from Khatauli, Gangnahar in Uttar Pradesh. The botanical samples were authenticated by the Botanical Survey of India (BSI) located in Noida, U.P. (Reference No.-BSI/BGIR/1/TECH./2024/98). The collected plants were dried in the shade, then separated and ground using a mechanical grinder. The powdered material was sieved through a 40-mesh screen. Chemicals such as ethanol and chloroform used for pharmacognostical analysis were sourced from Kumar Chemicals, Soot Ki Mandi, Kasganj-207123 (U.P.).

Pharmacognostical studies

Macroscopic evaluation

For macroscopic evaluation, fresh samples of *P. australis* were collected from their natural habitat and carefully cleaned to remove soil, dust, and extraneous matter. The whole plant was first observed for its general appearance, colour, height, and growth habit, noting its tall, erect stature and rhizomatous spread[32].

Powder microscopy

To examine the microscopic characteristics of *P. australis,* dried plant powder was first treated with chloral hydrate, which acts as a clearing agent to remove cellular debris and enhance visibility of internal structures. The cleared sample was then stained using a 1:1 mixture of phloroglucinol and hydrochloric acid. This staining combination specifically highlights lignified tissues, such as vessels and fibers, by producing a reddish colouration[33].

A drop of glycerine was placed on a clean glass slide to serve as a mounting medium, preserving the sample and preventing dehydration. The stained powder was transferred onto the slide, covered with a cover slip to flatten the specimen, and gently pressed to eliminate air bubbles. The prepared slide was then observed under a compound microscope[34].

Physicochemical parameter

Physicochemical parameters provide the essential basis for pharmacognostic evaluation. Assessing factors such as moisture content, ash values, and extractive yields allows researchers to verify the identity of plant material, identify adulteration, and maintain uniform quality in herbal preparations. These preliminary tests are indispensable and must be performed prior to phytochemical screening and pharmacological investigations[35].

Preliminary phytochemical screening

Standard qualitative procedures were conducted to identify the detection of carbohydrates, tannins, glycosides, flavonoids, alkaloids, phenols, and saponins following established protocols[36].

Preparation of plant extracts of *P. australis*

The plant powder of *P. australis* was extracted with water, chloroform, and ethanol by cold maceration for 72 h. The extracts were concentrated after being filtered with Whatman filter paper[36-38].

Water, chloroform, and ethanol were selected to span a broad polarity gradient, thereby maximising the range of bioactive constituents recovered from the plant matrix and allowing a comparative assessment of how solvent polarity influences photoprotective efficacy. Ethanol, a moderately polar solvent, is well established for its efficiency in extracting flavonoids, phenolic acids, and tannins, the constituents most strongly implicated in UV absorption and antioxidant activity[39]. Water, being highly polar, was included to recover hydrophilic constituents

such as glycosides and mucilaginous polysaccharides, consistent with the traditional aqueous-based preparation of *Phragmites* species in ethnomedicine[23]. Chloroform, a non-polar solvent, was used to isolate lipophilic constituents such as sterols and lower-polarity phenolic derivatives that are not accessible to the more polar solvents. Together, this three-solvent scheme follows standard pharmacognostic practice for the preliminary chemical characterisation of previously unexplored plant material and ensures that no major class of photoprotective phytoconstituent is systematically excluded from evaluation[40].

Sun protective activity of different extracts

Sample preparation

An accurately weighed 0.2 g of the extract was transferred into a 100 ml volumetric flask, diluted to volume with ethanol, and filtered through cotton to obtain a 2000 ppm stock solution. After discarding the initial 10 ml of the filtrate, a 25.0 ml aliquot was transferred to a 50 ml volumetric flask and diluted to volume with ethanol to prepare a 1000 ppm solution. Subsequently, another 25.0 ml aliquot of this solution was transferred to a separate 50 ml volumetric flask and diluted to volume with ethanol to yield a 500 ppm working solution[40-41].

In vitro evaluation of SPF using the mansur equation

The sun protection factor of each extract was determined by Mansur's spectrophotometric technique. Approximately 0.2 g of each extract (water, chloroform, and ethanol) was weighed, transferred to a 100 ml volumetric flask, diluted to volume with ethanol, and filtered. The initial 10 ml of filtrate was discarded[42-43]. From the remaining solution, a 25 ml aliquot was taken and further diluted to 50 ml with ethanol. Before UV spectrophotometric measurement, ethanol was used to adjust the final concentration of the sample. Absorbance readings were taken three times at wavelengths within 290 and 320 nm (UV-B region) at 5 nm divisions[44].

$$SPF_{spectrophotometric} = CF \times \sum_{290}^{320} EE(\lambda) \times I(\lambda) \times Abs(\lambda)$$

Where CF is the correction factor (10), EE (λ) is the erythmogenic effect of radiation with wavelength λ, and Abs (λ) is the spectrophotometric absorbance values at wavelength λ. The values of EE x I are constants[45-49].

Statistical analysis

All assays were carried out in triplicate, with results expressed as the mean ± SD to ensure reliability and reproducibility.

Results and Discussion

The pharmacognostic assessment verified the identity of *P. australis* by highlighting its characteristic morphological and microscopic traits. This species is recognized as a tall, erect perennial grass that flourishes in wetlands, marshes, and riparian zones, commonly attaining heights between 2 and 6 meters. It propagates primarily through extensive rhizomatous growth, enabling the formation of dense clonal colonies that dominate its habitat. Such growth habit, together with its large feathery panicles, serves as a dependable set of diagnostic features for species authentication. These markers not only distinguish *P. australis* from related grasses but also provide a foundation for ensuring accuracy and consistency in pharmacognostic and phytochemical investigations.

Morphological characters of *P. australis* mentioned in Table 1 and Fig. 1.

The dried powder of *P. australis* microscopy examination revealed several diagnostic features that are characteristic of the species. These included the presence of calcium oxalate crystals, which appeared as distinct crystalline structures, cork cells forming protective tissue layers, and vessels

Table 1. Morphological characters of *Phragmites australis*

S. No.	Plant part	Morphological character
1	Whole plant	Tall, perennial grass; forms dense clonal stands via rhizomes; height 2–6 meters
2	Leaves	Alternate, linear-lanceolate; 20–60 cm long; sheath encloses stem
3	Leaf blades	Flat, tapering to a fine point; parallel venation; glabrous or slightly rough
4	Leaf margin	Entire (smooth), sometimes slightly scabrous (rough to touch)
5	Surfaces of leaf	Upper surface smooth and green; lower surface paler, may have fine hairs near base
6	Flowers	Arranged in large, feathery panicles (20–40 cm); bisexual spikelets with 3–7 florets
7	Petals	Absent; replaced by lodicules (2–3 small, scale-like structures) typical of grasses
8	Sepals	Absent; represented by glumes and lemmas enclosing florets
9	Carpels	One per floret; ovary superior with two feathery stigmas
10	Fruit	Caryopsis (typical grass fruit); small, dry, one-seeded, enclosed by persistent lemma
11	Seeds	Small, light brown; dispersed by wind or water; low germination compared to vegetative spread

Figure 1. Macroscopic characteristics of *Phragmites australis*: (a) flower/panicle, (b) leaf, (c) culm, (d) rhizome The flower of the *Phragmites australis* plant is found in a large, bushy, feathery cluster called a panicle. (b) The leaves of the *Phragmites australis* plant are long, narrow, blue-green, and rough-textured, growing alternately on the stems. (c) It has a single thick stalk or culm that ends in an inflorescence. The culms can be up to 19.5 feet (6 meters) tall. (d) Rhizomes of *Phragmites australis* exceed 15 mm in diameter and are a darker yellow than the introduced lineage

with lignified walls that aid in conduction. Mucilage cells were also observed, contributing to the plant's storage and protective functions. Together, these microscopic markers serve as reliable pharmacognostic identifiers, ensuring the authenticity and quality control of *P. australis* in powdered form **(Fig. 2).**

Physicochemical analysis showed moderate moisture content (9.4%) and a notably high water-soluble extractive value (9.23%). These parameters suggest good stability and a strong potential for yielding hydrophilic bioactive compounds. Such characteristics are essential for maintaining quality standards in herbal preparations and minimizing risks of microbial contamination (Table 2).

Phytochemical screening confirmed the presence of flavonoids, phenolic compounds, tannins, and saponins across all extracts. These metabolites are widely recognized for their antioxidant and UV-absorbing properties, directly supporting the plant's potential role in photoprotection. The consistency of these findings across solvent systems reinforces the versatility of *P. australis* as a source of bioactive compounds (Table 3).

The *in vitro* SPF evaluation revealed clear differences among extracts. Ethanol extract exhibited the highest

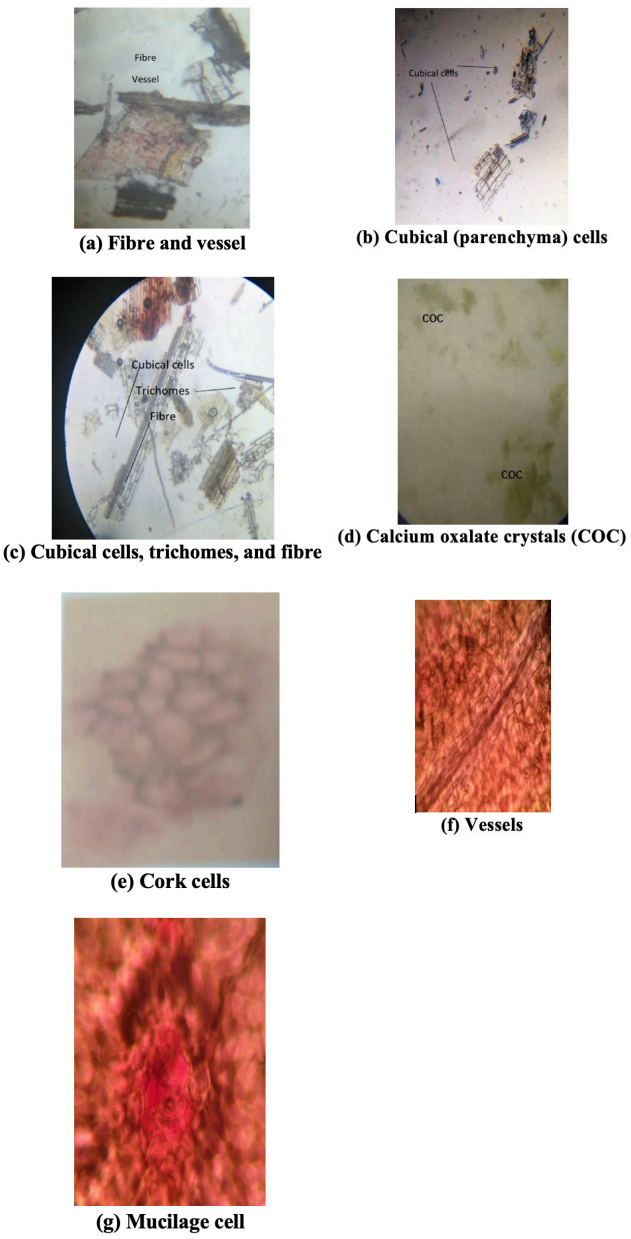

Figure 2. Powder microscopy of *Phragmites australis* **(**Diagnostic microscopic features of the dried powder of *Phragmites australis*: (a) fibre and vessel, (b) cubical (parenchyma) cells, (c) cubical cells, trichomes, and fibre, (d) calcium oxalate crystals (COC), (e) cork cells, (f) vessels, (g) mucilage cell)

SPF value (11.025 ± 0.022), while chloroform (2.2699 ± 0.003) and aqueous (1.5338 ± 0.016) extracts showed comparatively lower activity (Table 4). The superior performance of the ethanol extract highlights the importance of solvent polarity in concentrating flavonoids and phenolic acids, which are known to absorb UV-B radiation effectively. This finding indicates that extraction solvent directly influences the *in vitro* photoprotective performance

Table 2. Physicochemical parameters of *Phragmites australis*

S. No.	Physicochemical parameters	*Phragmites australis*
1	Loss on drying	9.4%
2	Ash value	
	Total ash value	4.5%
	Water insoluble ash value	1.8%
	Acid insoluble ash value	2.65%
3	Extractive value	
	Alcohol soluble extractives	3.47%
	Water soluble extractives	9.23%

Table 3. Preliminary phytochemical screening of *Phragmites australis* extracts

Chemical constituents	Aqueous extract	Chloroform extract	Ethanol extract
Alkaloids	+	-	+
Glycosides	+	-	-
Flavonoids	+	+	+
Carbohydrates	+	-	+
Saponins	+	+	+
Phenolic compounds and Tannins	+	+	+
Test for protein	+	+	+
Test for oils & fats	-	-	-
Test for amino acid	-	-	-
Test for resin	-	-	-

Table 4. Sun protection factor values of all extracts of the *Phragmites australis* plant

Type of extract	Sun protection factor
Aqueous	1.5338 ± 0.016
Chloroform	2.2699 ± 0.003
Ethanolic	11.025 ± 0.022

of the extracts and provides practical guidance for future formulation strategies, which will require *in vivo* validation (Table 5) (Fig. 3–6).

Limitations and future research directions

This study has several limitations that should be considered when interpreting the findings. First, SPF was determined entirely *in vitro* by spectrophotometric absorbance using the Mansur equation on crude extracts; this method estimates UVB-range photoprotection (290–320 nm) from a solvent solution and does not account for UVA protection, critical wavelength, or photostability, nor does it reflect how an extract would perform once incorporated into an actual topical formulation and applied to skin. Second, phytochemical screening in this study was qualitative only; without total phenolic and total flavonoid content assays or chromatographic fingerprinting (e.g., HPLC or LC-MS), the specific compounds and their concentrations responsible for the observed SPF differences could not be quantified or confirmed. Third, the plant material was collected from a single site and time point, so seasonal, geographic, and inter-batch variability in phytochemical composition and SPF performance remain unassessed. Fourth, no cytotoxicity, dermal irritation, sensitisation, or other safety data were generated for any of the three extracts; their suitability for topical or cosmetic use is therefore unknown. Finally, the extracts were not evaluated for photostability, i.e., whether their UV-absorbing capacity is retained after prolonged light exposure, which is essential for any real-world sunscreen application.

Future work should address these gaps along several directions.

1. **Quantitative phytochemical profiling:** total phenolic and total flavonoid content assays (e.g., Folin-Ciocalteu and aluminium chloride colorimetric methods), together with HPLC or LC-MS fingerprinting, to identify and quantify the specific constituents driving photoprotective activity and enable a genuine structure-activity correlation with SPF.
2. **Formulation development:** incorporation of the ethanolic extract into representative topical bases (e.g., creams, gels, or lotions) followed by re-evaluation of SPF, spreadability, stability, and compatibility with excipients, since formulation matrices can substantially alter the photoprotective performance of a raw extract.
3. **Photostability assessment:** evaluation of the extract's and the finished formulation's UV-absorbing capacity after simulated and prolonged sunlight exposure, to determine whether the phytoconstituents responsible for SPF degrade over the course of realistic use.
4. **Cytotoxicity evaluation:** *in vitro* cytotoxicity and phototoxicity assays (e.g., MTT assay on keratinocyte cell lines such as HaCaT) to establish a safe concentration range prior to any dermatological application.
5. **Skin safety evaluation:** dermal irritation and sensitisation testing, using validated *in vitro* reconstructed skin models in the first instance, followed by human-volunteer patch testing and, ultimately, *in vivo* SPF determination (e.g., per ISO 24444) once a stable, safety-cleared formulation is available.
6. **Broader validation:** assessment of batch-to-batch and seasonal variability in raw material composition, and comparison of alternative, potentially higher-

Table 5. SPF values of aqueous, chloroform & ethanol extracts of *Phragmites australis*

S. No	Nm	EE x I	Absorbance- Aqueous extarct of *Phragmites australis*	EE x I x Abs.	Absorbance- Chloroform extarct of *Phragmites australis*	EE x I x Abs.	Absorbance- Ethanol extarct of *Phragmites australis*	EE x I x Abs.
1	290	0.015	0.2062	0.003093	0.286	0.00429	2.1032	0.02062
2	295	0.082	0.1815	0.014829	0.2567	0.020972	1.7523	0.1815
3	300	0.287	0.1635	0.04699	0.2355	0.067683	1.5233	0.1635
4	305	0.328	0.1565	0.051301	0.2243	0.073526	1.882	0.1565
5	310	0.186	0.1345	0.025071	0.2162	0.0403	0.6845	0.1335
6	315	0.084	0.125	0.010488	0.1998	0.016763	0.3842	0.125
7	320	0.018	0.1143	0.002057	0.1922	0.00346	0.3841	0.1143
	SPF			1.5338		2.2699		11.025

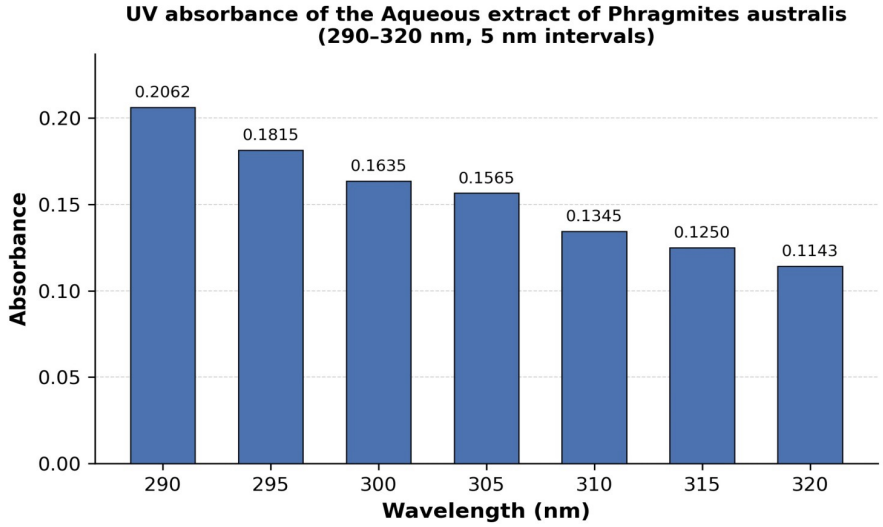

Figure 3. UV absorbance of the aqueous extract of *Phragmites australis* across 290–320 nm (5 nm intervals), used to calculate its *in vitro* SPF (1.5338) via the Mansur equation

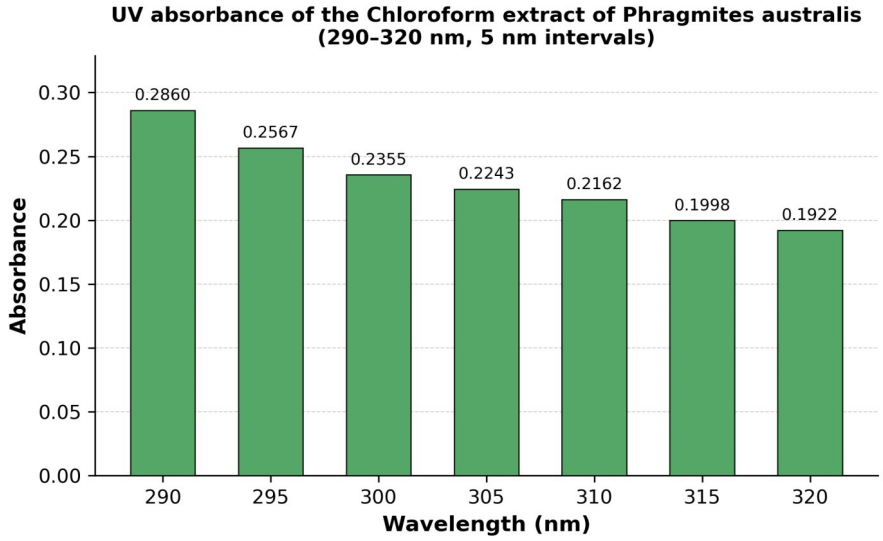

Figure 4. UV absorbance of the chloroform extract of *Phragmites australis* across 290–320 nm (5 nm intervals), used to calculate its *in vitro* SPF (2.2699) via the Mansur equation

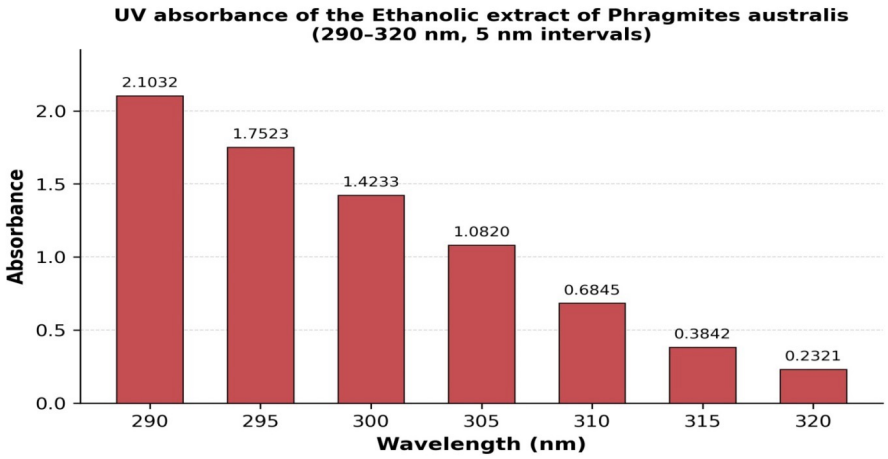

Figure 5. UV absorbance of the ethanolic extract of *Phragmites australis* across 290–320 nm (5 nm intervals), used to calculate its *in vitro* SPF (11.025) via the Mansur equation

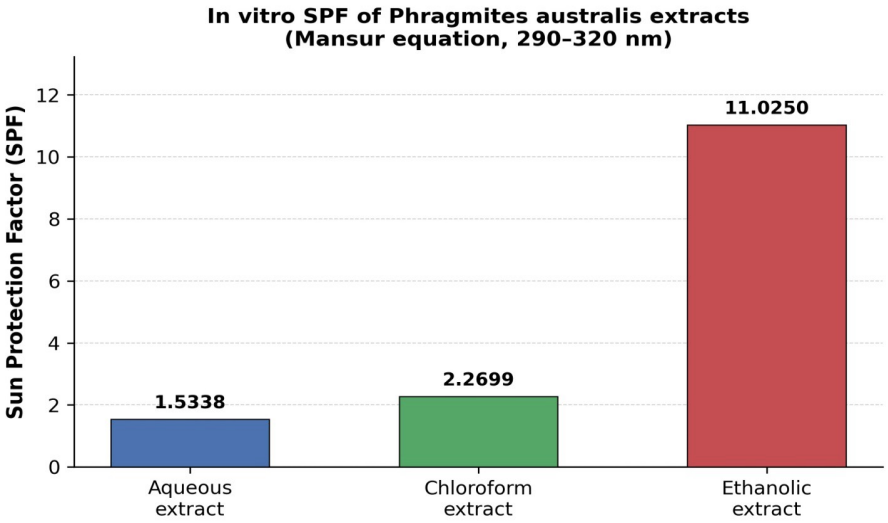

Figure 6. Comparative *in vitro* sun protection factor (SPF) values of the aqueous, chloroform, and ethanolic *Phragmites australis* extracts, calculated via the Mansur equation from UV absorbance measured between 290 and 320 nm at 5 nm intervals (Figures 3–5)

yield extraction techniques (e.g., ultrasound- or microwave-assisted extraction) against the cold maceration method used here.

Only once these steps are completed can *P. australis* extracts be meaningfully evaluated as candidates for actual sunscreen or skincare products.

Conclusions

This investigation highlights the rich phytochemical composition of *P. australis* and its notable *in vitro* sun-protective potential. Among the tested extracts, ethanol demonstrated the highest SPF value, reflecting strong UV-B absorption capacity and pronounced antioxidant activity. The consistent presence of flavonoids, phenolic compounds, and tannins further emphasises the plant's pharmacological importance in dermatological applications.

Owing to its wide ecological distribution, sustainable growth, and traditional medicinal relevance, *P. australis* demonstrates strong potential as a source for developing natural, plant-derived sunscreen formulations. As these results are based solely on *in vitro* spectrophotometric determination of SPF for crude extracts, they should be regarded as preliminary rather than as validation of photoprotective efficacy or safety. Formulation into finished cosmetic bases, stability and dermal safety testing, and *in vivo* or human-volunteer SPF evaluation are necessary before *P. australis* extracts can be considered for actual sunscreen or skincare applications.

Conflict of interest

The authors declared no conflict of interest.

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