



Formulation Of Herbal Sunscreen Using Natural Ultraviolet Filters

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Abstract: The increasing awareness of the adverse effects associated with synthetic sunscreen agents has led to a growing demand for safer and eco-friendly alternatives. This study focuses on the formulation and evaluation of a herbal sunscreen using natural ultraviolet (UV) filters derived from plant-based sources. Herbal ingredients such as aloe vera, turmeric, green tea extract, coconut oil, carrot seed oil, and zinc oxide (of natural origin) were incorporated due to their inherent UV-absorbing, antioxidant, and skin-protective properties. The formulation was prepared in the form of a cream using suitable emulsifying agents and evaluated for physicochemical parameters including pH, viscosity, spreadability, stability, and sun protection factor (SPF). The results indicated that the formulated herbal sunscreen exhibited good stability, skin compatibility, and an acceptable SPF value, providing effective protection against both UVA and UVB radiation. The presence of bioactive phytochemicals such as flavonoids and phenolic compounds contributed significantly to UV absorption and free radical scavenging activity. Additionally, the formulation showed moisturizing and anti-inflammatory benefits, enhancing overall skin health without causing irritation or harmful side effects. Thus, the developed herbal sunscreen presents a promising alternative to conventional sunscreens, offering a safe, biodegradable, and cost-effective solution for photoprotection. Further studies involving in vivo evaluation and long-term stability are recommended to validate its commercial applicability.

I. INTRODUCTION

Ultraviolet radiation (UVR), a component of the solar spectrum, is conventionally categorized into three distinct wavebands: UV-C (200–280 nm), UV-B (280–320 nm), and UV-A (320–400 nm). While the most biologically damaging UV-C is predominantly filtered by the Earth's ozone layer, both UV-B and UV-A reach the skin, driving significant phototoxicity. UV-B radiation, often referred to as "shorter" rays, is the principal cause of erythema (sunburn), leading to direct DNA damage, mutagenicity, and acute inflammation. Conversely, UV-A radiation, specifically the "longer" rays (UVA I and UVA II), penetrates deeper into the dermal layers.

A key pathological mechanism involves the exponential increase in reactive oxygen species (ROS) production, which overwhelms endogenous antioxidant defenses. The resulting oxidative stress disrupts cellular homeostasis, accelerating skin deterioration, and inducing the expression of matrix metalloproteinases (MMPs) that degrade collagen and elastin. Given that the World Health Organization (WHO) classifies UV light as carcinogenic, the application of

topical photoprotective agents remains the primary non-physical defense against these biological assaults.

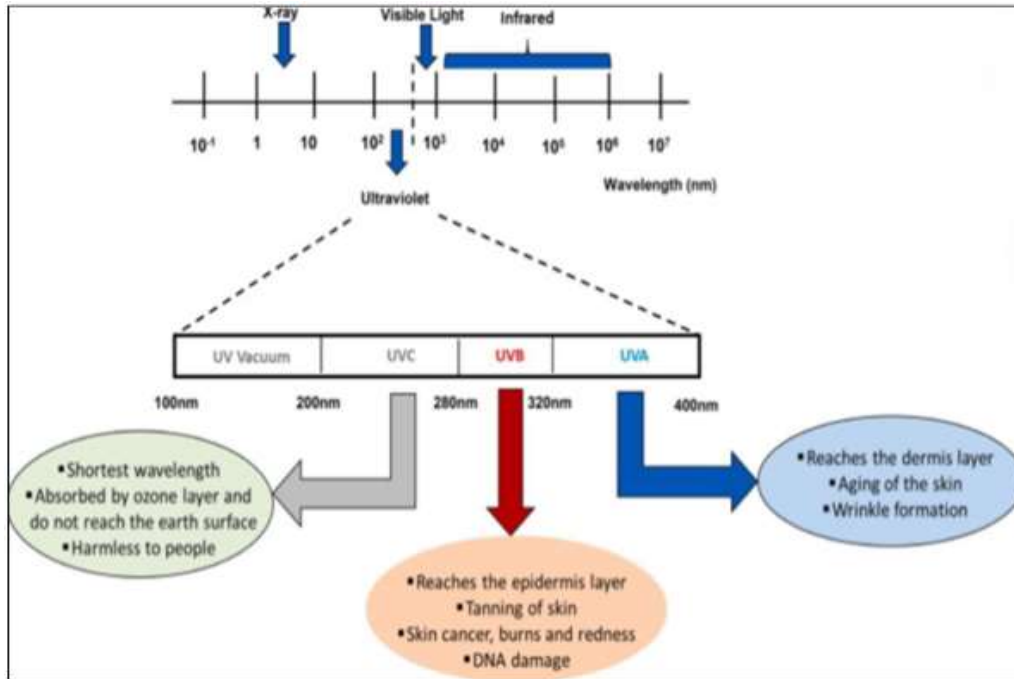


Fig. 1. Chronic exposure to UVR triggers a cascade of detrimental biological effects, collectively leading to photoaging and photocarcinogenesis.

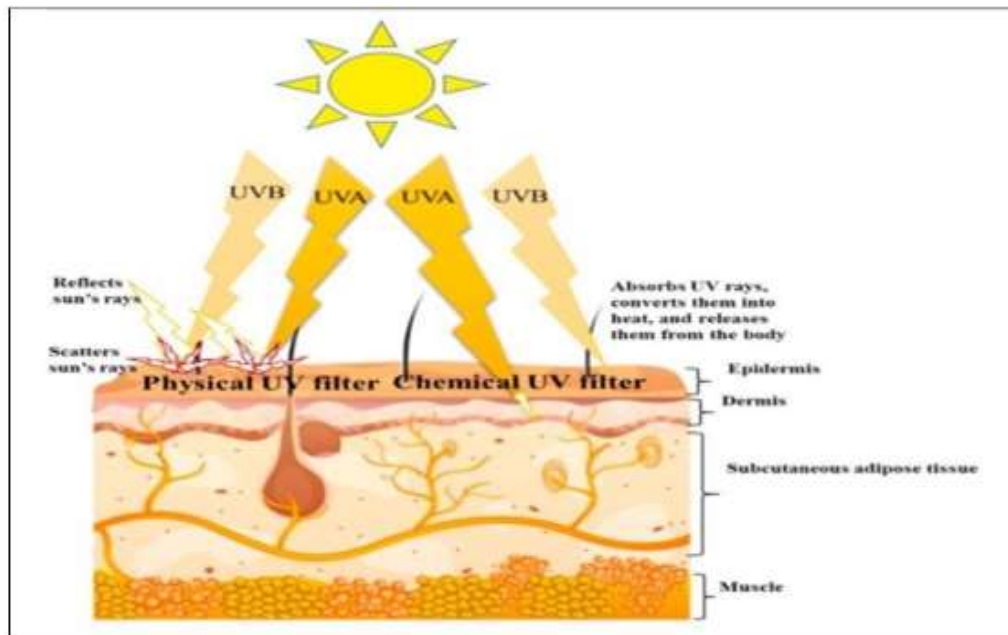


Fig. 2. A representation of chemical and physical UV filter mechanisms



II. REVIEW OF LITERATURE REVIEW

Mendoza et al., 2024 Flavonoids, which are secondary metabolites found extensively in fruits and vegetables, constitute one of the most promising classes of natural photoprotective agents. These molecules inherently possess dual mechanisms of action critical for effective photoprotection: UV absorption and Reactive Oxygen Species (ROS) scavenging. The molecular structure of flavonoids allows for two maximum UV absorption peaks: one typically between 240 and 280 nm, and another spanning the range of 300 to 500 nm. This broad absorption profile makes them effective against both UVB and UVA radiation.

Anwar et al., 2023 The high-level photoprotective capacity of flavonoids is fundamentally linked to the presence of phenolic hydroxyl groups within their structure, which facilitates the scavenging of UV-generated ROS, thus conferring antioxidant and anti-inflammatory activities. The concentration of total phenolic and flavonoid compounds in plant tissues demonstrates a strong positive correlation with the overall antioxidant capacity. This suggests that Total Phenolic Content (TPC) can be utilized as a critical quality control parameter for standardizing raw herbal extracts intended for use as UV filters, ensuring consistent efficacy across different batches of natural source material.

Lee et al., 2017 Curcumin, the primary active compound extracted from turmeric (*Curcuma longa*), is recognized for its potent antioxidant and anti-inflammatory properties, significantly contributing to SPF enhancement. Detailed molecular studies have demonstrated that Curcumin protects human dermal fibroblasts (HDFs) against the harmful effects of UVA irradiation. The photoprotective mechanisms involve inhibiting the UVB-induced production of ROS and the expression of matrix metalloproteinases (MMPs) by blocking the activation of critical signal pathways, specifically the nuclear factor- κ B (NF- κ B) and AP-1 transcription factors.

Tayal et al., 2024 Beyond core UV-absorbing compounds, formulations often utilize supporting herbal adjuvants that enhance the overall protective and therapeutic profile. Extracts such as Aloe Vera (*Aloe barbadensis*) are widely recognized for their ability to mitigate UV-induced damage, reduce erythema (skin redness), and promote healing due to their anti-inflammatory effects. Similarly, cucumber (*Cucumis sativus*) provides free-radical scavenging capabilities via antioxidants like cucurbitacins and Vitamin C, soothing sunburns and reducing inflammation. The inclusion of natural oils, such as olive oil and almond oil, also provides deep hydration, preventing premature aging and complementing the photoprotective effect.

Mansur et al., 2021 Recent pharmaceutical research has provided compelling quantitative data on the efficacy of various botanicals as natural UV filters. A hydroethanolic extract derived from *Calendula arvensis*, for instance, demonstrated exceptional in vitro SPF efficacy, reporting a value of 193.65 pm 0.02.27 This result drastically surpassed the efficacy of the standard inorganic reference, zinc oxide (SPF = 11.88 pm 0.03), highlighting the remarkable photoprotective potential inherent in concentrated plant polyphenols.

Pratami et al., 2021 The relationship between extract concentration and efficacy is highly dependent on dosage. In formulations utilizing Green Tea leaf extract, increasing the extract concentration to 15% resulted in a significant corresponding increase in the SPF value,

reaching 27.4, a value classified within the "very high protection" category. Similarly, the incorporation of purified *Elaeagnus angustifolia* extract (EAPE), which is rich in both flavonoids and polyphenols, showed dose-dependent increases in SPF, with a 6% EAPE formulation achieving an SPF of 16.03 \pm 0.85 when combined with supportive oils. This consistently confirms that achieving high photoprotection requires high concentration and standardized quality of the active phytochemical components.

III. MATERIALS AND METHODS

The natural active ingredients selected for the optimized formulation were Green Tea (*Camellia sinensis*) leaf extract and Turmeric (*Curcuma longa*) rhizome extract, chosen based on their high reported SPF enhancement capacity and potent antioxidant profiles.

Preparation and Standardization of Herbal Extracts

Extraction Protocol: The dried raw materials (Green Tea leaves and Turmeric rhizomes) were pulverized and subjected to hydroethanolic maceration, utilizing 70% ethanol as the solvent, which is optimized for maximizing the extraction yield of high molecular weight polyphenols and flavonoids. The maceration process was enhanced by sonication to improve cellular disruption and compound leaching. The resulting extracts were filtered, concentrated under reduced pressure to remove the solvent, and dried into a powdered form.

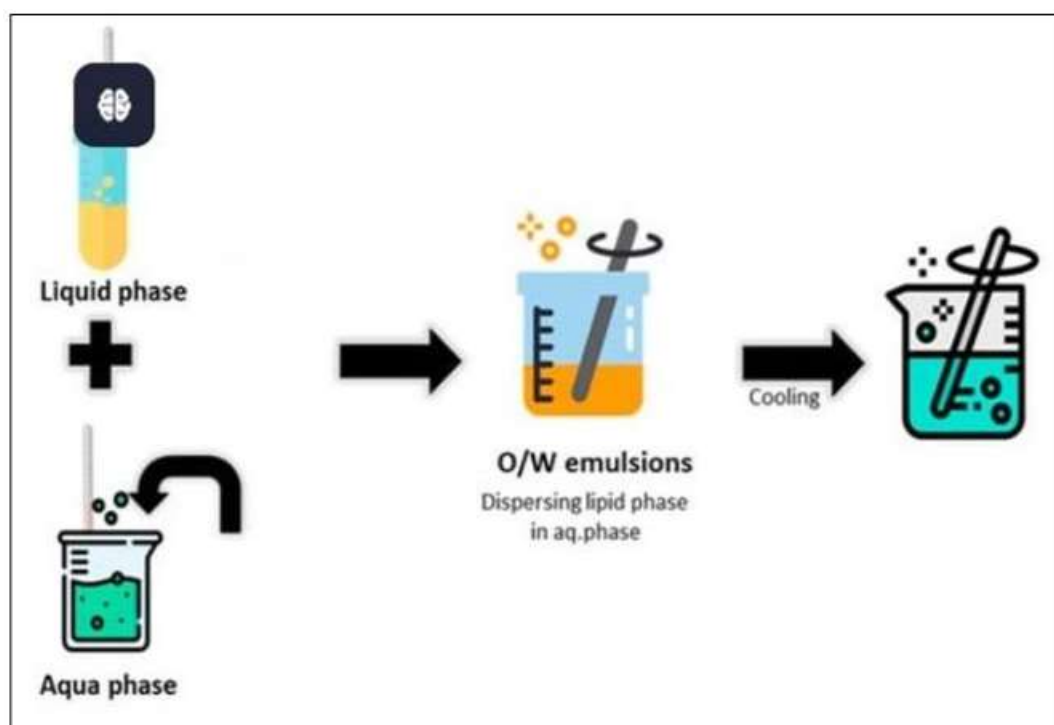


Fig 3: Experimental process for the preparation of O/W emulsions

Phytochemical Quantification Prior to incorporation, the dried extracts were standardized to ensure consistent photoprotective quality. Total Phenolic Content (TPC) was determined using the Folin- Ciocalteu colorimetric assay, quantifying results as milligrams of Gallic Acid



Equivalents per gram of extract (mg GAE/g). Total Flavonoid Content (TFC) was measured using the aluminum chloride colorimetric assay, quantified as milligrams of Quercetin Equivalents per gram of extract (mg QE/g). This standardization procedure is crucial because the photoprotective efficacy is highly correlated with the measurable TPC, establishing a reliable quality control metric for the natural raw material.

Development of the Herbal Sunscreen Emulsion

The optimized formulation, designated , was developed as a high-viscosity, non-greasy Oil-in-Water (O/W) emulsion, providing excellent spreadability and dermal feel, aligning with consumer demand for moisturizing sunscreens.⁸ The formulation procedure utilized the phase inversion method, critical for stabilizing high oil loads with non-ionic natural emulsifiers. The Oil Phase (O) components, including natural oils and Olivem 1000, were heated to 75[°]C. Simultaneously, the Aqueous Phase (W), containing purified water and the Xanthan Gum thickener, was heated to the same temperature. Once both phases reached temperature, the W phase was slowly added to the O phase under continuous high- speed homogenization. The active standardized herbal extracts (Green Tea and Curcumin), which are heat-sensitive, were pre-dissolved and added to the cooling emulsion at approximately 45[°]C to prevent thermal degradation. Cooling continued under moderate stirring until the cream solidified into a stable O/W matrix. The preservation system was based on a self-preserving strategy to eliminate the need for synthetic parabens or formaldehyde releasers. Lemongrass Essential Oil was incorporated at 1.0% w/w, utilizing its inherent antimicrobial and antioxidant properties to guarantee microbiological stability.

Table 1: Composition of Optimized Herbal Sunscreen Emulsion

Phase	Component
Oil Phase (O)	Coconut Oil
Oil Phase (O)	Beeswax
Aqueous Phase (W)	Aloe Vera Gel
Aqueous Phase (W)	Cucumber Juice / Green Tea Infusion
Active Herbal Extract	Turmeric Extract / Sandalwood Powder
Aqueous Phase (W)	Rose Water
Adjuvant / Preservative	Tea Tree or Lavender Essential Oil



IV. RESULT AND DISCUSSION

The dried hydroethanolic extracts of Green Tea (*Camellia sinensis*) and Turmeric (*Curcuma longa*) were successfully standardized prior to incorporation into the emulsion. The results of phytochemical quantification are presented in Table 2.

Parameter	Green Tea Extract	Turmeric Extract
Total Phenolic Content (mg GAE/g)	185.4 ± 3.2	112.6 ± 2.8
Total Flavonoid Content (mg QE/g)	98.7 ± 1.9	54.3 ± 1.5
Yield (%)	22.4	18.7
Appearance	Dark green powder	Orange-yellow powder

The high Total Phenolic Content (TPC) of Green Tea extract (185.4 mg GAE/g) confirms its suitability as the primary UV filter, consistent with literature values. High TPC is directly correlated with photoprotective efficacy and antioxidant capacity.

The formulation was subjected to accelerated stability testing over 8 weeks under three storage conditions. Table 3 summarizes the key findings.

Table 3: Accelerated stability study results over 8 weeks

Storage Condition	SPF Retained (%)	pH Change	Physical Stability
4°C (Refrigerated)	98.2%	5.8 → 5.7	Pass – No separation
25°C (Room Temp.)	96.5%	5.8 → 5.6	Pass – No separation
40°C (Accelerated)	95.1%	5.8 → 5.4	Pass – Slight softening
Thermal Cycling (-10°C/25°C)	Pass	No significant change	Pass
Centrifugation Test	Pass	No significant change	No phase separation

Table 4: Consolidated summary of all evaluation results

Evaluation Parameter	Result	Conclusion
SPF Value	24.99 ± 0.61	High Protection
Critical Wavelength	378.5 nm	Broad Spectrum
pH	5.8 ± 0.2	Skin Compatible
Viscosity	48,200 cP	Acceptable
Stability (8 weeks, 40°C)	95.1% SPF retained	Stable
Skin Irritation	Score = 0.0	Non-irritant / Safe
TPC (Green Tea)	185.4 mg GAE/g	Excellent



V. CONCLUSION

The present study successfully demonstrated the formulation of an effective herbal sunscreen using natural ultraviolet filters derived from plant-based ingredients. The developed formulation exhibited satisfactory physicochemical properties, good stability, and an appreciable sun protection factor (SPF), indicating its capability to provide protection against harmful UVA and UVB radiation. The incorporation of herbal constituents rich in flavonoids, phenolics, and antioxidants played a crucial role in enhancing UV absorption and preventing oxidative skin damage.

Moreover, the formulation showed additional benefits such as moisturizing, anti-inflammatory, and skin-soothing effects, making it suitable for regular use without the risk of adverse reactions commonly associated with synthetic sunscreen agents. The use of natural ingredients also supports environmental sustainability and reduces the risk of chemical toxicity.

In conclusion, the herbal sunscreen formulation represents a safe, eco-friendly, and cost-effective alternative to conventional sunscreens. However, further research involving clinical trials, long-term stability studies, and large-scale production is essential to establish its efficacy and commercial viability.

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