



INVESTIGATION OF THE ANTIOXIDATIVE AND SUN-PROTECTIVE PROPERTIES OF *Aegle marmelos* AND *Cardiospermum halicacabum* HERBAL EXTRACTS

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Medicinal plants are rich natural sources of bioactive phytochemicals and are widely used in the cosmetic industry due to their compatibility in types, with fewer side effects. Therefore, it is essential to assess their phytochemical composition to determine the potential of these indigenous plants as valuable sources of medicinal and cosmetic applications. This study aims to evaluate the Sun Protection Factor (SPF) and the antioxidant activity of *Aegle marmelos* (Beli/Bael) and *Cardiospermum halicacabum* (Welpenela) through their leaf extract, as both plants are traditionally used in cosmetics and in the treatment of various human infections. Leaves from both plant species were subjected to hot water extraction, and a dilution series was prepared using ethanol as solvent to assess SPF. A UV-spectrophotometer was used to determine the absorbance values across the 290–320 nm wavelength range, and SPF values were calculated based on the Mansur equation. The experimental data were analysed using the paired sample *t*-test to compare the mean values between *Aegle marmelos* and *Cardiospermum halicacabum* extracts. Antioxidant activity was measured using the hydrogen peroxide scavenging assay. According to the Mansur equation, *Cardiospermum halicacabum* exhibited SPF values ranging from 0.315 to 1.296, while *Aegle marmelos* ranged from 0.324 to 1.194. Both extracts had a maximum SPF value at the highest concentrations and then steadily decreased with dilution. *Cardiospermum halicacabum* had a slightly higher average SPF (mean = 0.707) than *Aegle marmelos* (mean=0.698), but the difference was not statistically significant ($p>0.05$), indicating comparable UV protection capacity. The hydrogen peroxide scavenging assay revealed that both leaf extracts possessed antioxidant properties. Comparatively, *A. marmelos* extract demonstrated stronger antioxidant activity, with up to 54.2% scavenging activity than 28.9% in *C. halicacabum*. Both leaf extracts showed UV-absorbing and antioxidant properties, with *Aegle marmelos* showing slightly higher activity in hydrogen peroxide scavenging and comparable sun protection potential, indicating its potential as a natural bioactive ingredient for skin-protective formulations. Despite phytochemical analyses, proper clinical cosmeceutical trials are needed to evaluate the appropriate efficacy of these natural products in addressing dermal needs.

Keywords: sun protection factor, antioxidant activity, hydrogen peroxide

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INTRODUCTION

The use of natural cosmetics is increasingly gaining popularity among consumers due to the rising awareness of environmental sustainability and health consciousness. Products labelled as “natural” are often perceived as safer and more eco-friendly alternatives to synthetic formulations. This shift in consumer preference reflects a growing interest in cosmetics that align with environmental preservation, personal well-being, and sustainable consumption practices. However, the users of natural and organic skincare products actively seek evidence-based assurances that such products are genuinely derived from natural sources and offer tangible health benefits (Rathi et al., 2017).

One of the major health concerns associated with personal care is excessive exposure to ultraviolet (UV) radiation, which leads to skin damage, premature ageing, sunburn, and in severe cases, skin cancers. Among the types of UV radiation—UV-A, UV-B, and UV-C—only UV-A and UV-B reach the Earth’s surface and are primarily responsible for damaging human skin. UV-B radiation (280–320 nm) is more energetic and causes sunburn, while UV-A (320–400 nm) penetrates deeper into the skin and contributes to photoaging and DNA damage. Therefore, sun protection products that can shield the skin from both UV-A and UV-B rays are essential.

Therefore, plant-derived antioxidants have attracted significant attention as natural photoprotective agents. Many plant extracts are rich in phenolic compounds, flavonoids, tannins, and vitamins, which have the ability to absorb UV radiation and neutralize free radicals generated by UV exposure. These antioxidants play a crucial role in protecting skin cells by preventing oxidative stress through free radical scavenging mechanisms.

Cardiospermum halicacabum, belonging to the family *Sapindaceae*, is a traditional medicinal plant with known anti-inflammatory, antimicrobial, and wound-healing properties. It is widely used in Ayurvedic and Siddha medicine and is gaining traction in modern cosmeceuticals for its bioactive profile. *Aegle marmelos*, from the family *Rutaceae*, is another highly valued medicinal plant in South Asian



traditional medicine. Its leaves, fruits, and bark are rich in phytochemicals such as marmelosin, aegeline, and various polyphenols, which contribute to its antioxidant, antimicrobial, and hepatoprotective properties.

Despite the long-standing use of these plants in traditional medicine, there is limited scientific evidence supporting their efficacy as components in natural sun protection and antioxidant formulations. Consequently, their use in herbal cosmetics remains underexplored and underutilized.

This study was carried out to evaluate and compare the sun protection factor (SPF) and antioxidant activity of *Aegle marmelos* and *Cardiospermum halicacabum* leaf extracts. The goal is to assess their potential as bioactive ingredients in natural sunscreen formulations and promote their application in eco-friendly skincare products. By identifying and validating these plant species for cosmetic use, this research supports both biodiversity conservation and the reduction of synthetic chemical usage in skincare paving the way for more sustainable and health-conscious personal care alternatives.

METHODOLOGY

Plant extraction and sun protection factor determination.

Fresh *Aegle marmelos* and *Cardiospermum halicacabum* leaves were collected, thoroughly cleaned, and cut into small pieces. The leaves were then dried before the hot water extraction. For each plant, 20 mg of dried leaf material was mixed with 200 mL of distilled water and heated at 90–95 °C for 30–60 minutes. The extract was then concentrated to approximately 30 mL, filtered, and stored in a McCartney bottle at refrigerated conditions.

A dilution series was prepared from the original extract by mixing with 70% ethanol, resulting in final concentrations of 0.1 mg/mL, 0.01 mg/mL, and 0.001 mg/mL with Vivya sunscreen (SPF 45), was used as the standard reference.

The Sun Protection Factor (SPF) values were calculated from absorbance readings at wavelengths ranging from 290 nm to 320 nm using the Mansur equation:

$$(\text{SPF}=\text{CF} \sum_{320}^{290} \text{EE}(\lambda) \times \text{I}(\lambda) \times \text{Abs}(\lambda)) \text{ (Priyanka et al., 2018).}$$

The prepared plant extract at a concentration of 0.667 mg/mL was diluted to obtain the working solution for the antioxidant assay. This solution was mixed with phosphate buffer and hydrogen peroxide (H₂O₂) to evaluate its H₂O₂ scavenging activity. After a 10-minute incubation period the absorbance of the reaction mixture was measured.

Ascorbic acid was used as the positive control for comparison. The percentage of hydrogen peroxide scavenging activity was calculated using the following formula:



Scavenging activity = (Absorbance of the control - Absorbance of the sample) $\times$ 100% / Absorbance of the control. This method was adapted from Gupta et al. (2022) and Dutta et al. (2020).

Statistical analysis

The experimental data were analysed using the paired sample *t*-test in R software to compare the mean values between *Aegle marmelos* and *Cardiospermum halicacabum* extracts. This method was used to assess whether there was a statistically significant difference in SPF values and antioxidant activity between the two plant samples at corresponding concentrations. A significance level of $p < 0.05$ was used to determine statistical significance.

RESULTS AND DISCUSSION

Antioxidant activity was evaluated using the hydrogen peroxide (H₂O₂) scavenging assay, while sun protection ability was assessed through SPF (Sun Protection Factor) calculations using the Mansur equation.

The SPF values obtained for *Cardiospermum halicacabum* ranged from 0.315 to 1.296, and for *Aegle marmelos*, from 0.324 to 1.194, across the tested concentrations. In both extracts, the highest SPF values were observed at the highest concentration, with a gradual decline upon dilution. Although *Cardiospermum halicacabum* exhibited a slightly higher mean SPF (0.707) compared to *Aegle marmelos* (0.698), the difference was not statistically significant ($p > 0.05$), indicating that both extracts offer comparable UV-protective potential. This difference is likely due to the presence of flavonoids and tannins in *C. halicacabum* that enhance UV absorption, while the stronger antioxidant activity of *A. marmelos* is associated with its higher polyphenol content. Thus, both species show comparable potential as natural photoprotective agents.

The hydrogen peroxide scavenging assay further confirmed that both plant extracts possess antioxidant activity. Among them, *Aegle marmelos* demonstrated stronger H₂O₂ scavenging ability, with a maximum activity of 54.2%, whereas *Cardiospermum halicacabum* showed up to 28.9% (Figure 01 shows the antioxidant percentages of *Cardiospermum halicacabum* and *Aegle marmelos* within 0.1 mg/ml and 0.01 mg/ml). *Aegle marmelos* showed stronger hydrogen peroxide scavenging activity, likely due to its higher levels of polyphenols, flavonoids, and antioxidant compounds like marmelosin and aegeline, which effectively neutralize reactive oxygen species. These phytochemicals help reduce oxidative stress by donating hydrogen atoms or electrons to free radicals. In contrast, *Cardiospermum halicacabum* also contains bioactive compounds. However, its profile is more associated with anti-inflammatory and antimicrobial effects rather than direct radical scavenging, which may explain its lower activity. Factors such as extraction efficiency, leaf maturity, and growing conditions could also have influenced the



measured antioxidant potential. However, the observed difference in antioxidant activity between the two extracts was not statistically significant at the 95% confidence level ($p > 0.05$), suggesting variability within the samples.

Overall, both *Cardiospermum halicacabum* and *Aegle marmelos* leaf extracts exhibited UV-absorbing and antioxidant properties. While *Aegle marmelos* showed relatively higher antioxidant capacity, both extracts presented comparable photoprotective efficacy. These findings support the potential of *Aegle marmelos* and *Cardiospermum halicacabum* as natural bioactive ingredients in skin-protective formulations, offering antioxidant benefits and moderate UV protection.

The lack of statistically significant differences in both SPF and antioxidant assays suggest that both extracts are comparable in terms of their bio efficacy, making them promising candidates for natural cosmeceutical applications. However, the variability observed—especially in antioxidant capacity—highlights the need for further studies using purified compounds, larger sample sizes, and multiple antioxidant assays (e.g., DPPH, ABTS) to validate and extend these findings.

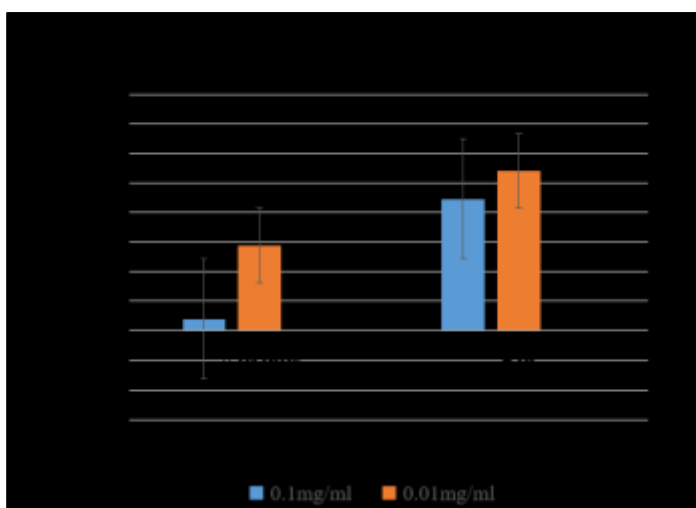


Figure 01- Antioxidant percentages of *Cardiospermum halicacabum* and *Aegle marmelos* within 0.1 mg/ml and 0.01 mg/ml

CONCLUSION

This study highlights the potential of *A. marmelos* and *C. halicacabum* leaf extracts as natural agents with antioxidant and photoprotective properties. Both extracts demonstrated measurable sun protection factors (SPF) and hydrogen peroxide scavenging activity, indicating their capacity to neutralize oxidative stress and absorb harmful UV radiation. Although *A. marmelos* exhibited relatively higher antioxidant activity and *C. halicacabum* showed slightly greater SPF values, these differences were not statistically significant, suggesting comparable efficacy. The



findings support the use of these plant extracts as promising candidates for incorporation into skincare or sunscreen formulations as natural, bioactive ingredients. Further research, including in vivo assessments and formulation studies, is recommended to validate their effectiveness and safety in practical applications.

ABBREVIATIONS

SPF	Sun protection factor
UV	Ultraviolet
H ₂ O ₂	Hydrogen peroxide
DPPH	2, 2-diphenyl-1-picrylhydrazyl
ABTS	2,2-azino-bis-3-ethylbenzothiazoline-6-sulphonic acid
CF	10 (correction factor)
EE (λ)	erythemogenic effect of radiation at wavelength λ
I (λ)	intensity of solar light at wavelength λ
abs (λ)	absorbance of wavelength λ by a solution of the preparation.

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