

Formulation and Evaluation of a Mineral-Based Sunscreen Containing *Centella asiatica*

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ABSTRACT

Excessive exposure to ultraviolet (UV) radiation leads to skin damage, photoaging, and increased risk of dermatological disorders, highlighting the need for safe and effective sunscreen formulations. The present study aimed to formulate and evaluate a mineral-based sunscreen cream incorporating *Centella asiatica*, a medicinal plant known for its antioxidant, anti-inflammatory, wound-healing, and skin barrier-repair properties. Titanium dioxide and zinc oxide were used as physical UV filters to provide broad-spectrum photoprotection, while *Centella asiatica* extract and exosomes were included to enhance skin tolerance and therapeutic efficacy.

The plant material was authenticated and subjected to Soxhlet extraction, yielding essential oil with acceptable extraction efficiency. Preliminary phytochemical screening confirmed the presence of flavonoids, alkaloids, phenols, glycosides, tannins, and lipids. The sunscreen cream was prepared using an oil-in-water emulsion method and evaluated for physicochemical parameters such as pH, spreadability, viscosity, extrudability, washability, irritability, and stability. The formulation exhibited suitable pH, smooth texture, good homogeneity, non-irritant behavior, and acceptable stability. Although SPF values were modest, the formulation demonstrated good cosmetic acceptability and enhanced skin-friendly properties, making it suitable for sensitive skin. [1]

Keywords: Mineral sunscreen, SPF testing, UV protection, titanium dioxide, zinc oxide.

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INTRODUCTION

The skin consists of up to seven layers of ectodermal tissue that shield underlying muscles, bones, ligaments, and organs. It closely resembles the skin of other mammals, especially pigs. The term "cutaneous" derives from the Latin word *cutis*, meaning skin. As the body's largest organ and a key part of the integumentary system, skin defends against pathogens and prevents excessive water loss. It also provides insulation, regulates temperature, enables sensation, produces vitamin D, and safeguards vitamin B folates. [2]

Structure of Skin

Human skin mirrors the anatomical, physiological, biochemical, and immunological traits of other mammals. It comprises three main layers—epidermis, dermis, and hypodermis—that collaborate to sustain homeostasis and serve as a barrier and interface with the external environment. Composed primarily of water, proteins, fats, and minerals, the skin features mesodermal cells like melanocytes, which generate melanin to absorb harmful ultraviolet (UV) radiation from sunlight. [3] This pigmentation, along with DNA repair enzymes, helps mitigate UV damage; deficiencies in these enzymes elevate skin cancer risk.

The skin's diversity supports a microbiome of around 1,000 bacterial species from 19 phyla.

Structure of Skin: [4]

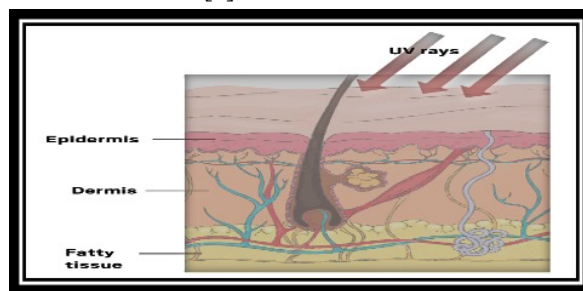


Fig. No. 1: Structure of Skin UV Rays

Layers of the Skin[5]

Skin consists of three main layers: the epidermis (outer), dermis (middle), and hypodermis (deepest). These layers work together to protect the body, regulate temperature, and support overall function.

Epidermis

The outermost epidermis, derived from Greek "epi" meaning "upon," forms a waterproof shield over the body. Composed of keratinocytes that release cytoplasm and fill with keratin, it blocks pathogens, UV rays, and environmental damage. Key functions include constant cell renewal (replacing ~40,000 shed

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cells daily for full turnover every 30 days), immune defense via Langerhans cells, and pigmentation through melanin, which determines skin tone and aids UV protection. [6,7]

Dermis

Beneath the epidermis lies the dermis, a connective tissue layer anchored by a basement membrane that cushions against mechanical stress. It divides into the papillary region (loose areolar tissue with finger-like papillae extending upward) and reticular region (dense irregular tissue rich in collagen, elastic, and reticular fibers for strength and flexibility). [8]

Hypodermis

The deepest hypodermis (subcutaneous fat) safeguards muscles and bones from impact, links skin to deeper structures, and expands nerves/blood vessels from the dermis. Primarily adipose tissue, it insulates and absorbs shock during falls. [9]

Skin Types: [10,11]

- Normal: Balanced, tolerant to weather/products without excess oil or dryness.
- Oily: Overproduces sebum, leading to shine; needs mattifiers.
- Dry/Dehydrated: Lacks oil (dryness: flaky/itchy) or water (dehydration: tight).
- Combination: Oily T-zone with dry cheeks.
- Acne-prone: Excess sebum clogs pores, causing inflamed pimples.
- Sensitive: Reacts to irritants due to genetics/environment.
- Mature: Thins, wrinkles, and dries with age.

Skin Functions

Skin stores lipids/water, synthesizes vitamin D via UV, excretes urea through sweat, protects via immune cells/lysozyme, senses touch/heat, regulates temperature through vessel dilation, controls evaporation, resists water loss, absorbs select substances (e.g., patches), and aids aesthetics. [12]

Creams

Creams are semi-solid emulsions (oil-in-water or water-in-oil) applied topically for moisturizing, protection, or therapy. Oil-in-water (O/W) types disperse oil droplets in water for light feel; water-in-oil (W/O) suspends water in oil for richer occlusion. [13]

MATERIALS AND METHODS

Selection of Active Ingredient: *Centella asiatica*-derived exosomes served as the primary active due to their proven benefits in wound healing, reducing inflammation, combating oxidation, and restoring the

skin barrier. These exosomes carry bioactive triterpenoids like asiaticoside, madecassoside, asiatic acid, and madecassic acid, which stimulate collagen production, blood vessel growth, and tissue repair. As plant-based nanocarriers, they boost cellular signaling, enhance active compound delivery into skin layers, and offer biocompatibility with minimal immune response, making them ideal for topical treatments targeting irritated or damaged skin. [14,15]

Collection and Authentication: Healthy *Centella asiatica* leaves were gathered from pesticide-free cultivated sites, rinsed thoroughly with distilled water to eliminate debris, and dried in shade at ambient temperature. A botanist from the Department of Botany verified the plant through macroscopic and microscopic features, following pharmacognostic standards; a voucher specimen was archived in the herbarium for reference. [16]

Isolation and Authentication of Exosomes:

Exosomes from *Centella* leaf extract were separated via differential centrifugation followed by ultracentrifugation, then purified and frozen at -20°C for storage. [17] Confirmation involved particle size and zeta potential assessments, plus morphological checks with transmission electron microscopy (TEM), alongside detection of exosomal markers through biochemical or molecular assays. [18]

Extraction Method: Soxhlet extraction enables continuous solvent-based removal of compounds from solids. The sample sits in a porous thimble that retains solids while permitting solvent flow. Solvent heats to reflux, vapors ascend to a condenser for liquefaction, then percolate through the sample, extracting solubles before siphoning back to the reservoir for reuse. [19]



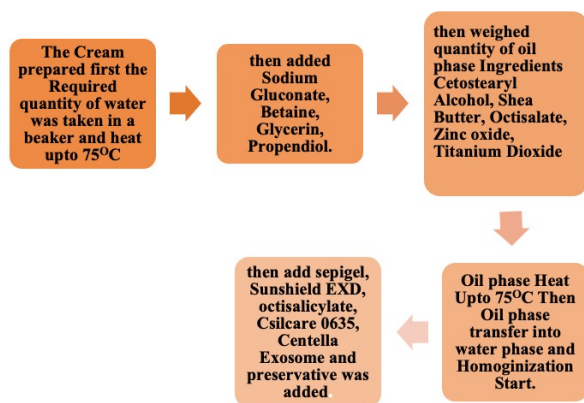
Fig. No. 2: Soxhlet apparatus

- Procedure of Extraction of *Centella* oil by Soxhletion

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Preparation of Cream base



Preparation of Mineral Based Sunscreen Procedure

Water phase ingredients sodium gluconate, betaine, glycerin, and propanediol—were measured into a beaker and heated to 75°C. Oil phase components, including cetostearyl alcohol, shea butter, octisalate, zinc oxide, and titanium dioxide, were combined separately and also warmed to 75°C. [20] The oil phase was then emulsified into the water phase under homogenization, followed by addition of Sepigel, Sunshield EXD, octisalate, Csilcare 0635, Centella exosomes, and preservative. [21]

Formulation of Mineral Based Sunscreen

a. pH: A digital pH meter measured the cream's pH at 6.5, a skin-friendly value that minimizes irritation risk. [22]

b. Spreadability: Spreadability gauges how easily cream disperses from a tube onto skin. A sample on a glass slide, topped with another slide and 100 g weight, spread 6.5 cm in 5 minutes. Calculated as $S = m \times l / t = tm \times l$, where m is weight, l is slide length, and t is time. [23]

$$S = m \times l / t$$

Were;

S=Spreadability

m =Weight placed on the slide

l =Length of the glass slide

t =Time taken in seconds

c. Extrudability: A crimped tube was pressed to extrude a 0.5 cm ribbon in 10 seconds; required pressure averaged 15.3 g/cm². [24]

d. Viscosity: Using a Brookfield DV2T viscometer at 25°C, 50 rpm, a 5 g sample yielded 1050 centipoise after 5-minute settling. [25]

e. Irritability: Patch application caused no reactions, confirming non-irritancy; the cream rinsed off easily with water. [26]

f. Washability: A small amount of Cream was applied externally on the skin surface, and it was washed with running water. It was found to be easily washable. [27]

g. Loss on drying: 1 g cream dried at 105°C for 30-minute intervals in a hot air oven, cooled in a desiccator; consecutive weights determined moisture loss. [28]

Evaluation of extract

Preliminary Phytochemical Screening

- **Flavonoids:** Added NaOH to extract; yellow color fading with acid signals presence.
- **Glycosides:** Dissolved alcoholic extract in water, added NaOH; yellow hue indicates glycosides.
- **Alkaloids (Mayer's test):** Mixed mercuric chloride and potassium iodide reagent with acidic extract; blue-green precipitate confirms alkaloids. [29]
- **Phenols (ferric chloride test):** Alcoholic extract diluted with water and 10% FeCl₃; blue-green color denotes phenols.
- **Tannins (lead acetate test):** Aqueous extract with 1% lead acetate; yellow-red precipitate shows tannins.
- **Lipids:** Lipids: Sample with sodium bisulfate released pungent glycerin odor from oil hydrolysis. [30]

RESULTS AND DISCUSSION

Evaluation of Extract:

Preliminary Phytochemical Screening:

Table No. 1: Preliminary Phytochemical Screening

Sr. No.	Alkaloids	Flavonoids	Phenols	glycosides	Tannins	Lipids

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1	Essential Oils	+	+	+	+	+
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Here, + = Present, - = Absent

Evaluation parameters of Mineral Based Sunscreen

Table No.: 2: Determination of Evaluation parameters of prepared sunscreen cream

Parameters	F1	F2	F3
Appearance	Cream like	Cream like	Cream like
Color	Light Peach	Light Peach	Light Peach
Odor	Aromatic	Aromatic	Aromatic
Homogeneity	Uniform and homogeneous	Uniform and homogeneous	Uniform and homogeneous
Consistency	Good	Good	Good
Texture	Smooth	Smooth	Smooth
Irritation	No	No	No
Spreadability	23.23	20.91	22.38
Washability	Good	Good	Good
pH	5.5	6.02	6.05
Rancidity	No pink color, no rancidity	No pink color, no rancidity	No pink color, no rancidity
Viscosity	46900	42648	44652
SPF	0.64	0.08	1.36
LOD	11.7%	11%	11.3%

Soxhletion Method

Result obtained by Soxhlet extraction is shown in Table below

Table No. 3: Weight of oil with respect to time

Weight of oil (g)	Time (mins)
0.4	250
0.5	500
0.6	750
0.80	1000
0.90	1200

Soxhlet extraction of *Centella asiatica* yielded 3.2 g of pure essential oil from a 100 g sample, equating to a 3.02% extraction efficiency. Oil volume was monitored every 4 hours to track yield progression over time. Extended extraction duration caused ethanol solvent depletion, concentrating the remaining oil in the mixture.

Table No. 4: Result of Essential Oils Extraction

Method of extraction	% yield
Soxhletion Method	3.02

Material Balance for Soxhletion Method

- Weight of centella asiatica = 120g
- Quantity of Olive oil used= 600ml, Quantity of Ethanol used= 140ml
- Weight of beaker= 97.86g
- Weight ethanol and essential oil= 100.88g
- The total weight= 3.02g
- %yield = ME/MC x 100

Where

- ME = Mass of essential oil, MC = Mass of centella asiatica Sample
- ME = 3.02g
- MC = 120g
- By substituting values
- %yield = $3.02/120 \times 100 = 2.51\%$
- Therefore % yield= 2.51%

Graph of the weight (g) of essential oil to the time (mins) for extraction method

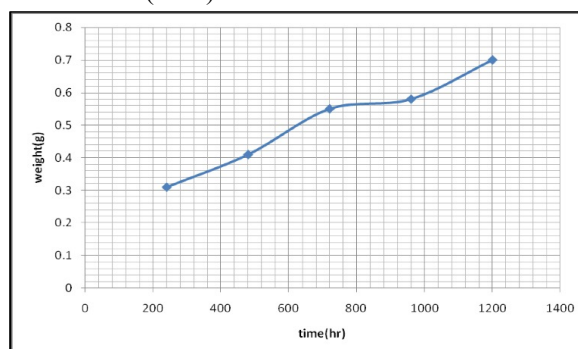


Fig. No. 3: Graph of the weight (C) of essential oil to the time (mins) for Soxhletion Method

CONCLUSION

In this research work, a mineral-based sunscreen cream incorporating *Centella asiatica* was successfully developed and systematically evaluated. The formulation combined physical UV filters with a plant-derived active known for its soothing, antioxidant, and skin-repairing properties. The prepared sunscreen exhibited satisfactory physicochemical characteristics, including appropriate pH, smooth texture, good spreadability, acceptable

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viscosity, ease of extrusion, and absence of skin irritation, confirming its suitability for topical use.

Phytochemical evaluation of the *Centella asiatica* extract revealed the presence of important bioactive compounds, supporting its functional role in enhancing skin protection and barrier health. The Soxhlet extraction method provided an effective yield of essential oil, demonstrating its applicability for isolating plant actives used in cosmetic formulations. Stability studies showed no signs of rancidity, phase separation, or inconsistency, indicating good formulation stability.

Although the measured SPF values were modest, the use of mineral UV blockers along with *Centella asiatica* exosomes offers complementary benefits such as reduced irritation, improved skin tolerance, and added antioxidant support. These characteristics make the formulation particularly suitable for sensitive and acne-prone skin types. Further studies focusing on SPF optimization, photostability testing, and in vivo evaluation are recommended to enhance protective efficacy and support future commercial development.

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CONFLICTS OF INTEREST

Authors have no conflicts of interest to declare.

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