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Review Article

Development and Evaluation of Herbal Sunscreen Formulation Utilizing Synergistic Potential of Clitoria Ternatea and Cucumis Sativus

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A paradigm shift toward the investigation and creation of herbal substitutes has been sparked by this. The potential of two well-known medicinal plants, Clitoria ternatea (butterfly pea) and Cucumis sativus (cucumber), as active ingredients in a unique, broad-spectrum herbal sunscreen formulation, Strong antioxidant and anti-inflammatory qualities, which are essential for reducing UV-induced oxidative stress and inflammation, are exhibited by Clitoria ternatea, which is rich in flavonol glycosides and anthocyanins like ternatins. Ascorbic acid, flavonoids, and phenolic compounds are found in Cucumis sativus, which has important cooling, moisturizing, and free radical-scavenging properties. In addition to providing intrinsic UV absorption, the synergistic combination of these botanicals is thought to provide a strong resistance against the secondary oxidative damage brought on by UV exposure. This article outlines an organized training module for comprehending the science underlying the creation of herbal sunscreens, from basic photobiology to sophisticated formulation methods. It offers a thorough process for extracting, standardizing, and creating a cream-based sunscreen that contains hydroglycolic extracts of C. sativus and C. ternatea. A thorough evaluation process is described, including stability studies in accordance with ICH criteria, in vitro Sun Protection Factor (SPF) calculation using UV spectrophotometry, and physicochemical parameters (pH, spreadability, and viscosity). The expected findings, which are mostly influenced by the phytoconstituents of the plant extracts, point to a stable formulation with favorable cosmetic qualities and a high SPF rating.

Keywords: Clitoria ternatea, Cucumis sativus, UV radiation, Sun protection, Flavonoids, UV spectrophotometry, SPF rating, radical-scavenging properties.

INTRODUCTION

Prolonged exposure to solar ultraviolet (UV) radiation leads to various harmful effects on the skin. These effects include sunburn, increased skin pigmentation, early aging, and the development of skin cancer. The major cause of UV-induced skin damage is the production of reactive oxygen species (ROS), which interact with skin proteins and lipids, resulting in their structural damage. Ultraviolet radiation is classified into three regions: UVC (200–280 nm), UVB (280–320 nm), and UVA (320–400 nm). Among these, UVB and, to a lesser extent, UVA radiation are mainly responsible for causing skin damage Sunscreens are widely used to protect the skin from UV radiation and are effective in preventing sunburn. However, several studies have reported that conventional sunscreens may not provide complete protection against skin cancer and premature skin aging. It is now clearly established that ROS play a key role in the development of skin disorders such as photoaging, actinic keratosis, and skin cancer caused by long-term exposure to sunlight. Therefore, the addition of antioxidants along with UV filters in sunscreen formulations can significantly enhance their protective effects against photoaging and skin

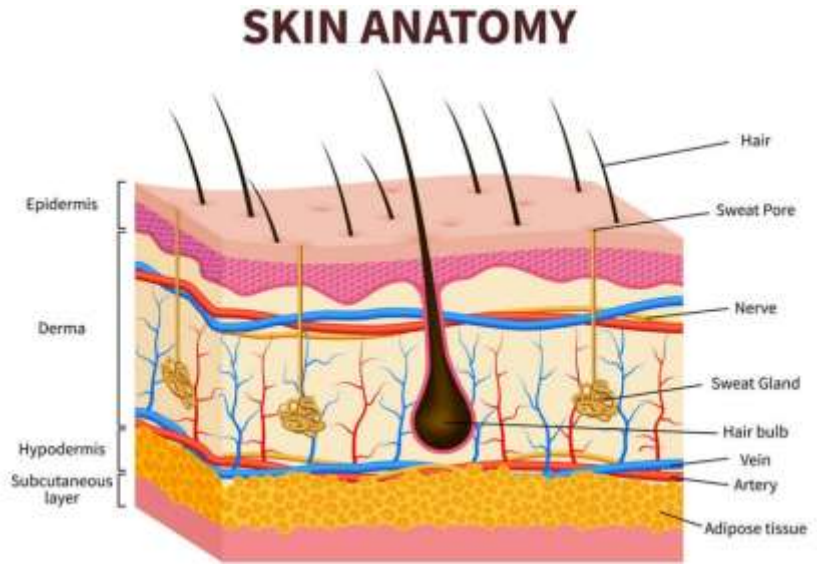
carcinogenesis. The effectiveness of herbal ingredients in improving skin health and treating various skin disorders is well documented. Due to their strong antioxidant potential, plant-based materials have gained considerable attention as promising natural ingredients in sunscreen formulations for the prevention of skin damage caused by solar radiation.

Skin:

The human skin is the largest organ of the body, acting as a protective barrier that regulates heat, water loss, and prevents the entry of harmful microorganisms, chemicals, and UV radiation. It covers approximately 1.7 m^2 of the body surface. Skin also enables drugs applied topically to act both locally and systemically. As a physical barrier, it controls the transport of substances mainly through pores and intercellular pathways. Although some drugs show promising in vitro penetration through the skin, they must be evaluated carefully to avoid potential immunological reactions or damage to the barrier.

Skin Structure and Anatomy:

Human skin is a complex, multilayered organ and serves as the main route for transdermal drug delivery. It is composed of four major layers, each contributing to protection, thermoregulation, and absorption of external agents.



1. **Stratum Corneum (Non-viable Epidermis):** Outermost layer Made of dead, flattened keratinized cells acts as the primary barrier against water loss and chemical penetration major obstacle for drug diffusion

2. **Viable Epidermis:** Contains living keratinocytes, melanocytes, and Langerhans cells Responsible for skin renewal, pigmentation, and immune defense No blood vessels present; nutrients come from the dermis

3. **Dermis:** Thick, supportive connective tissue layer Rich in collagen, elastin, blood vessels, hair follicles, sweat glands, and sebaceous glands Provides strength, elasticity, and nourishment to the epidermis

4. **Subcutaneous Fat Layer (Hypodermis):** Deepest layer Made of adipose tissue Provides cushioning, insulation, and energy storage Contains larger blood vessels and nerves.

Effects of Ultraviolet (UV) Radiation on Skin:

Sunlight contains a wide range of wavelengths, including ultraviolet (UV) and visible light. UV radiation is classified into:

- UVA (320–400 nm) – deeply penetrates the skin; causes aging and pigmentation

- UVB (290–320 nm) – affects the upper skin layers; causes sunburn and DNA damage

- UVC (100–290 nm) – absorbed by the ozone layer; does not reach Earth

Various Effects of UV Radiation on Human Skin

1. Photoaging: Skin aging is a multifactorial process divided into:

a) Intrinsic Aging

- Natural aging caused by genetics
- Leads to thin, dry skin and fine wrinkles

b) Extrinsic Aging

- Caused mainly by UV radiation
- Leads to deep wrinkles, pigmentation, rough texture, and loss of elasticity ● UVA is the major contributor

2. Skin Cancer: Continuous, unprotected exposure to UV radiation is a major cause of skin cancer. UVB is strongly linked to DNA mutations, while UVA contributes to deeper cellular damage. There are two major forms of skin cancer:

A. Melanoma Skin Cancer

Most aggressive and deadly type Linked to:

- UV exposure
- Severe sunburns
- Genetic mutations
- Immune suppression Starts in melanocytes (pigment cells) Rapidly metastasizes if untreated

B. Non-Melanoma Skin Cancer (NMSC)

Includes two common types:

1. **Basal Cell Carcinoma (BCC)**

- Slow-growing; rarely spreads to distant organs
- May invade deeper tissues and bone if untreated
- Appears as flesh-colored nodules, often on head, neck, or face

2. **Squamous Cell Carcinoma (SCC)**

- More aggressive than BCC
- Appears as red, scaly patches or nodules
- Can metastasize if not treated promptly
- Strongly linked to chronic UV exposure

Active Constituent and Their Mechanism:

1. Clitoria Ternatea (Butterfly Pea Plant)



Mechanism:

1. **Main Function:** Extensive UV Absorption the primary benefit arises from its distinct anthocyanins, chiefly ternatins. Ternatins (Polyacylated Anthocyanins): These blue pigments provide the flower with its vibrant hue. Their intricate chemical makeup consists of several aromatic rings and conjugated double bonds. This structure enables them to absorb a broad spectrum of UV radiation, especially within the UVA (320-400 nm) and UVB (290-320 nm) wavelengths. Mechanism: When UV photons strike the skin, these alternating molecules capture the energy from the photons, preventing deeper skin penetration and protecting the DNA in epidermal cells from damage. They function as a natural molecular "barrier."

2. **Secondary Mechanism:** Strong Antioxidant & Anti-Inflammatory Properties UV radiation not only inflicts direct harm; it also produces Reactive Oxygen Species (ROS) such as free radicals, leading to oxidative stress, inflammation, and the breakdown of collagen (photoaging). Packed with Flavonoids & Phenolic Acids: Butterfly pea contains not only anthocyanins but also a variety of antioxidants, including quercetin, kaempferol, and phenolic compounds. Function: These compounds capture and neutralize free radicals that arise from UV exposure. This: Decreases oxidative stress in skin cells. Reduces inflammation (such as redness and

sunburn). Assists in preventing long-term photoaging (wrinkles, loss of elasticity) by safeguarding collagen and elastin fibers.

3. **Supporting Mechanism:** Enhancement of Skin Barrier and Matrix Support Research indicates that polyphenols found in Butterfly Pea may positively impact the structural integrity of the skin. Collagen Preservation: By decreasing the activity of UV-induced matrix metalloproteinase (MMP) enzymes, it aids in preventing collagen degradation. Hydration: The extracts from this plant possess humectant qualities, which assist in sustaining skin moisture, essential for a resilient skin barrier capable of withstanding environmental challenges.

2. Cucumis Sativus (Cucumber)



Mechanism:

Cucumber (Cucumis sativus) serves in herbal sunscreens not as a main UV filter, but as an essential soothing, reparative, and hydrating support component that tackles the secondary harm caused by sun exposure. Its functioning is based on its distinct biochemical makeup. Comprising more than 95% water and rich in silica, cucumber delivers immediate cooling hydration and aids in strengthening the skin's barrier, enhancing its resilience. Even more importantly, it is packed with a variety of powerful antioxidants—including vitamin C, caffeic acid, and different flavonoids—that neutralize the free radicals produced by UV exposure, thus minimizing oxidative stress that contributes to photoaging. Additionally, cucumber is known for its considerable anti-inflammatory and vasoconstrictive effects, mainly due to its compounds such as cucurbitacins and sterols. This helps to alleviate erythema (redness), relieve burning sensations, and reduce inflammation linked to sunburn. In formulations, cucumber extract or juice works in harmony with main UV-blocking agents (like zinc oxide or other herbal filters such as Butterfly Pea) by mitigating the inflammatory repercussions of sun exposure, aiding in skin recovery, and providing a rejuvenating sensory experience. Therefore, its function is both preventive against damage and restorative, enhancing the sunscreen's skin-friendliness and effectiveness in maintaining skin health beyond just UV protection.

Sun Protection Factor (SPF) Determination:

Determining Sun Protection Factor (SPF) In vitro SPF values are expected to rise with higher concentrations of the herbal extracts, particularly C. ternatea. Table 3:

Expected SPF Values Derived from UV Spectrophotometry Formulation Expected

SPF Value Base (Control) 1 - 2 F1 (2% CT, 3% CS) 8 - 12 F2 (5% CT, 7% CS) 15 - 20

Market Synthetic Sunscreen (SPF 30) 28 - 32 The SPF is mainly due to the UV-absorbing flavonoids and anthocyanins present in C. ternatea. The combined antioxidant effect of both extracts enhances the overall photoprotective efficacy.

Stability Testing: The formulations kept at 5°C and 25°C are projected to exhibit no considerable changes in all assessed parameters over a period of 6 months. - Under accelerated conditions (40°C/75% RH), a slight alteration in color (diminution of the blue tint in F1 and F2) and a small reduction in viscosity may be detected after 3 months. The pH and SPF are predicted to remain mostly stable. - No signs of phase separation or microbial growth are expected in any of the appropriately preserved formulations.

Advantages:

1. Natural and Perceived Safety: Sourced from plants with a long-standing history of use in traditional practices, minimizing the likelihood of negative effects linked to synthetic compounds like oxybenzone.

2. Multifunctional Activity: The formulation serves more than just as a UV protector; it also offers

benefits such as antioxidant, anti-inflammatory, moisturizing, and possibly anti-aging properties.

3. Synergistic Effect: The blend of C. ternatea (for UV absorption) and C. sativus (for soothing and antioxidant effects) presents a comprehensive approach to photoprotection.

4. Environmental Sustainability: It is likely more biodegradable and less detrimental to marine ecosystems than certain synthetic UV filters.

5. Consumer Appeal: The association with being "clean," "green," and "natural" resonates with current market trends, appealing to an expanding consumer demographic.

6. Cosmetic Elegance: C. sativus provides excellent moisturizing and calming effects, enhancing the overall skin feel of the final product.

Formulation and Evaluation:

The formulation and evaluation of a herbal sunscreen containing Clitoria ternatea and Cucumis sativus are undertaken to develop a natural, safe, and skin-friendly photoprotective preparation. Clitoria ternatea is rich in anthocyanins and flavonoids that provide antioxidant activity and absorb harmful UV radiation, while Cucumis sativus offers soothing, moisturizing, and anti-inflammatory effects that help protect the skin from irritation and sun-induced damage. Evaluating the formulation for parameters such as SPF, pH, stability, spreadability, and skin compatibility ensures its effectiveness, safety, and suitability as a herbal alternative to synthetic sunscreens.

1. **Oil Phase:** Gently heat coconut oil, Shea Butter, and Bees wax together until melted. Add Cucumis sativus seed oil and Vitamin E. Mix well and keep warm.

2. **Water Phase:** Disperse Carbopol 940 in a mixture of Rose water and part of the Purified water. Allow it to swell. Separately, dissolve Methyl paraben in a small amount of warm water.

3. **Mixing:** Slowly add the oil phase to the water phase while stirring continuously (preferably with a homogenizer) to form an emulsion.

4. **Neutralization:** Add Triethanolamine dropwise to the emulsion to neutralize the Carbopol and form the gel-cream base. Adjust pH to 5.5-6.0.

5. **Herbal Addition:** Finally, incorporate the Clitoria ternatea extract and Aloe vera gel into the formed base. Mix thoroughly until uniform.

6. **Q.S:** Use the remaining Purified water to achieve the final weight (100g or 50g).

Ingredients	Standard Formula For 100g	Working Formula For 50g
Clitoria ternatea extract	5.0 g	2.5g
Cucumis sativus extract	3.0g	1.5g
Aloe vera gel	15.0ml	7.5ml
Coconut oil	8.0ml	4.0ml
Shea Butter	6.0g	3.0g
Bees wax	4.0g	2.0g
Carbopol	0.8g	0.4g
Rose water	45.0ml	22.5ml
Vitamin E (oil)	1.0ml	0.5ml
Triethanolamine (TEA)	0.4ml	0.2ml
Methyl paraben	0.2ml	0.1ml
Purified water	Q.s to 100ml	Q.s to 50ml

Evaluation Parameters

The prepared herbal sunscreen should be evaluated for the following: **A. Physical Evaluation & Stability Studies:**

1. Appearance & Organoleptic Properties

- Visual Inspection: Color, uniformity, phase separation.
- Texture & Consistency: Smooth, creamy, gel-like, or lotion-like.
- Odor: Characteristic herbal/ingredient smell; no rancid or off-odors.Feel: Non-greasy, easily absorbable, no gritty particles.

2. pH Measurement

- Method: Digital pH meter.
- Acceptable Range: pH 5.0–7.0 (skin-friendly, minimal irritation risk).
- Importance: Ensures compatibility with skin acid mantle.

3. Viscosity & Rheology

- Tools: Brookfield viscometer (spindle type, rpm specified).
- Report: Viscosity in centipoise (cP) or Pascal-seconds (Pa·s).
- Importance: Affects spreadability, packaging, and consumer acceptance.

4. Spreadability Method:

- Slip & Drag: Place sample between two glass slides, add weight, measure spread diameter.
- Parallel Plate: Measure time for fixed weight to spread over a marked circle.
- Target: Easy spreading with minimal effort

5. Extrudability / Flow Properties

- For Tubes: Force required to extrude product; should be smooth and consistent.
- For Pumps/Jars: Ease of scooping/dispensing. 6. Emulsion Stability Tests

a. Centrifugation Test

- Centrifuge at 3000–4000 rpm for 30 min.
- No phase separation indicates stable emulsion.

b. Freeze-Thaw Cycle Test

- Store at –5°C for 24 hrs, then 40°C for 24 hrs → repeat 3 cycles.
- Check for cracking, creaming, or separation.

c. Thermal Stability

- Keep at 40°C ± 2°C for 1–3 months (accelerated stability).
- Observe changes in consistency, odor, color, and phase.

B. Sun Protection Efficacy Evaluation

1. In-vitro SPF Determination (Spectrophotometric Method):

- This is the most accessible primary test.
- Dilute the sunscreen in ethanol/methanol.
- Scan absorbance from 290 nm to 320 nm (UV-B range) at 5 nm intervals.

Calculate SPF using the Mansur equation:

$$SPF = CF \times \Sigma EE(\lambda) \times I(\lambda) \times Abs(\lambda)$$

Where CF = Correction Factor (usually 10), EE = Erythemal Efficacy, I = Solar Intensity, Abs = Absorbance. Expected: A well-formulated cream with these activities should target an SPF of 15-25.

C. Skin Compatibility & Safety

1. Patch Test: Perform on 10-20 human volunteers. Apply a small amount on the forearm, cover, and observe after 24h and 48h for erythema, edema, or itching.
2. Irritancy Test: Can be performed on animal skin models (e.g., Albino rabbits) as per standard protocols if required.

D. Additional Functional Evaluation

1. Antioxidant Activity: Assess using DPPH radical scavenging assay on the final formulation to confirm the contribution of Ciltoria and Vitamin E.

2. Moisturization Effect: Use a corneometer to measure skin hydration before and after application on volunteers over time.

4. Rationale for Ingredient Selection in Sunscreen Context

Clitoria tematea (Butterfly Pea Flower): Rich in flavonoids (ternatins) and anthocyanins, known for strong UV absorption and antioxidant activity. It's the key herbal UV filter.

Aloe Vera & Rose Water: Provide soothing, cooling, and anti-inflammatory effects to counteract sun-induced irritation. Aloe vera also aids in healing.

Coconut Oil & Shea Butter: Natural emollients with minor UV absorption properties.

They improve skin barrier function and cream texture.

Bees Wax & Carbopol 940: Provide water resistance and stable cream/gel structure, crucial for even film formation on skin.

Vitamin E: Potent antioxidant that neutralizes free radicals generated by UV exposure (photoprotection from within).

Cucumis sativus (Cucumber): Adds anti-inflammatory and skin-cooling benefits, supporting the post-sun skin recovery claim.

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