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Research Article

Botanical Barrier- A Tri-Herbal Antioxidant Sunscreen: A Synergistic Approach to Enhanced Photoprotection

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ABSTRACT

The aim of present study was to formulate and evaluate a herbal sunscreen cream containing extracts of plant materials such as *Camellia sinensis* (green tea), *Salvia Rosmarinus* (rosemary) and *Solanum lycopersicum* (tomato). Oil in water (O/W) emulsion-based cream was prepared using these extracts as active pharmaceutical ingredients (APIs). The in vitro SPF value of cream was evaluated. The evaluation of cream was done on different parameters like pH, viscosity, spreadability, etc. and stability were examined. The prepared cream exhibited highest SPF value 15.10. The herbal cream showed good spreadability, good consistency, homogeneity, appearance, pH, ease of removal and no evidence of phase separation. The prepared herbal sunscreen creams was safe to use for skin.

INTRODUCTION

Tanning

Tanning is the process of skin darkening due to exposure to the UV radiation, mainly from sunlight. This occurs due to increase in the production of melanin pigment as a protective response against UV-induced damage. Tanning is not a sign of healthy skin, rather it indicates underlying skin damage.²



Figure 1: Tanning

Causes of Tanning

1. Exposure to Sunlight

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- Primary natural cause
- UV rays stimulate melanocytes - increased melanin - skin darkening

2. Ultraviolet (UV) Radiation

- UVA Rays
 - Penetrate deep into dermis
 - Can pass through glass
- UVB Rays
 - Affect epidermis
 - Cause Delayed Tanning
 - Responsible for sunburn and melanin synthesis

3. Blue Light

- Emitted from digital screens and indoor lighting
- Can contribute to pigmentation changes

4. Prolonged Outdoor Activities

- Farming, traveling, sports, outdoor jobs
- Increased UV exposure

5. Artificial UV Sources

- Tanning beds
- UV lamps
- Misuse of phototherapy devices

6. Lack of Sun Protection

- Not using sunscreen
- Using low SPF or no UVA protection
- No protective clothing or shade

7. Skin Type (Genetic Factors)

- Higher melanin → faster and deeper tanning
- Signs and Symptoms of Skin Tanning ^[1]:
Signs of Tanning (Visible Changes)

1. Darkening of skin
2. Uneven pigmentation (patchy/blotchy areas)
3. Dull or tanned appearance (loss of glow)
4. Hyperpigmentation (dark spots, freckles, melasma)
5. Skin thickening (rough/leathery texture in chronic exposure)

Symptoms of Tanning (Experienced Sensations)

1. Burning sensation
2. Warm or hot skin
3. Dryness and tightness
4. Mild itching or irritation
5. Increased sensitivity to sunlight

Severe / Associated Symptoms (Excessive Tanning)

1. Sunburn (redness, pain)
2. Peeling or flaking skin
3. Blister formation
4. Premature wrinkles and fine lines

Comparison of UV types:

Feature	UVA	UVB
Primary Effect	Tanning & Aging	Burning
Skin Penetration	Deep (Dermis)	Surface (Epidermis)
Glass Penetration	Yes	No

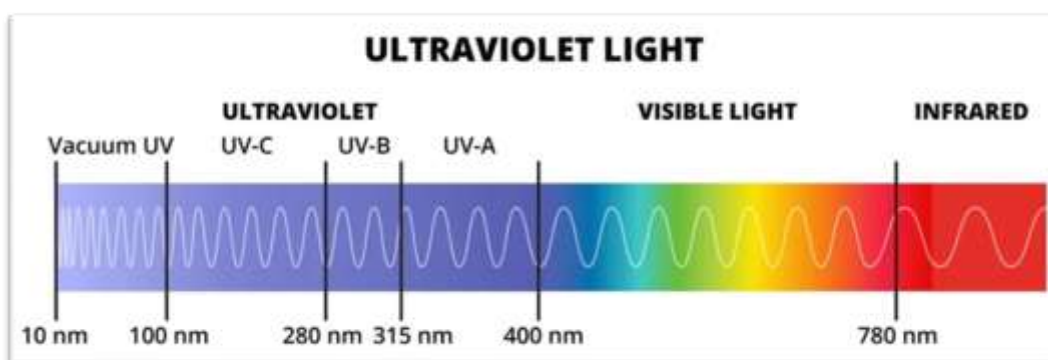


Figure.3: UV Scale

Prevention of Tanning ^[4]:

1. Use of Sunscreen

- Broad-spectrum (UVA + UVB)
- Minimum SPF 30 (SPF 50 for prolonged exposure)
- Apply 20–30 minutes before sun exposure
- Reapply every 2–3 hours

2. Protective Clothing

- Long-sleeved clothes
- Wide-brim hats, scarves
- UV-protective sunglasses

3. Avoid Peak Sun Hours

- Between 11:00 AM – 4:00 PM
- Stay in shade

4. Use Physical Barriers

- Umbrellas
- Face covers, masks
- Sun-protective gloves

5. Antioxidant Skin Care

- Vitamin C, Vitamin E, Niacinamide
- Herbal: Aloe vera, Green tea, Liquorice

6. Maintain Skin Hydration

- Regular moisturization
- Adequate water intake

7. Avoid Artificial UV Sources

- No tanning beds or UV lamps



Figure.3: Sunburn

Sunburn:

Sunburn is inflamed, painful skin that feels hot to the touch. It often appears within a few hours of

being in the sun too long. You can get sunburn relief with simple self-care measures such as taking pain relievers and cooling the skin. But it may take days for the sunburn to fade. It can be prevented year-round by wearing sunscreen or using other skin-protection habits is important for everyone. It is especially important when you're outdoors, even on cool or cloudy days.

Sunburn is red, painful, damaged skin from being out in the sun for too long. When you get a sunburn, ultraviolet (UV) rays from the sun (or a tanning bed!) burn your skin. Some people get sunburns doing everyday things without using sunscreen, like taking a lunch break outside, gardening or walking the dog.⁶

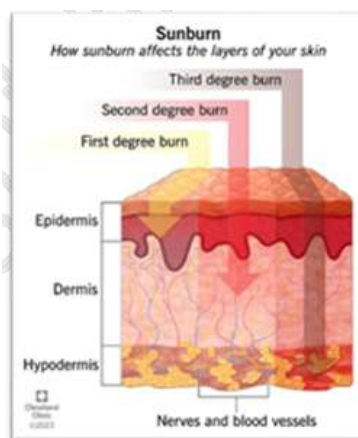


Figure.3: Sunburn

Sunscreen [7]:

Sunscreen is a topical preparation (gel, spray or lotion) that filters out the ultraviolet (UV) radiation from the sun.

(the rays that cause sunburn) is required to burn protected skin in comparison, to unprotected skin.

SPF 30 blocks about 97% of UVB rays.

SPF 50 blocks about 98% of UVB rays.

What is SPF?

SPF stands for Sun Protection Factor. It is a relative measure of the amount of UVB radiation

ACTIVE PHARMACEUTICAL INGREDIENTS:

Feature	Rosemary [11]	Green Tea [8]	Tomato
Botanical Name	<i>Salvia rosmarinus</i>	<i>Camellia sinensis</i>	<i>Solanum lycopersicum</i>
Family	Lamiaceae (Mint family)	Theaceae (Tea family)	Solanaceae (Nightshade family)
Common Synonyms	<i>Rosmarinus officinalis</i>	<i>Thea sinensis</i>	<i>Lycopersicon esculentum</i>
Origin	Mediterranean region	East Asia	South America (Andes)
Plant Type	Woody, perennial herb	Evergreen shrub/small tree	Perennial (often grown as annual)
Key Active Compounds	Rosmarinic acid, Carnosic acid, Eucalyptol ^[12]	Epigallocatechin gallate (EGCG) ^[9] , Caffeine	Lycopene, Vitamin C, Beta-carotene
Anti-oxidants	Carnosic acid, Carnosol	Polyphenols -catechins	Lycopene [13]
Use in the Formulation	Preservative Booster: Helps protect the olive oil from spoilage.	Antioxidant Protection: Neutralizes free radicals caused by UV exposure.	UV Protection Booster: Lycopene helps the skin defend itself against "Erythema" (Sunburn)



	Skin Soothing: Acts as a mild antimicrobial and tonic for the skin.	Anti-inflammatory^[10]: Reduces skin redness and irritation.	Anti-Aging: Helps prevent the breakdown of collagen caused by environmental stress. ^[14]
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Figure 4: Rosemary (*Salvia rosmarinus*)



Figure 5: Green Tea (*Camellia sinensis*)



Figure 6: Tomato (*Solanum lycopersicum*)

INFUSION TECHNIQUES:

Rosemary (*Salvia rosmarinus*) ^[18]

- **Lipid or Oil Maceration / Digestion-** By heating the rosemary powder in olive oil, we specifically targeted the Carnosic Acid.
- This ensures the oil phase of cream is protected from going rancid (oxidation).

Green Tea (*Camellia sinensis*) ^[16]

- **Aqueous Hot Infusion.** Since the catechins and caffeine are highly water-soluble, we used hot distilled water of up to 75°C -85°C to draw these molecules out of the leaf powder.

Tomato (*Solanum lycopersicum*) ^{[15] [17]}

- **Lipid Hot Infusion-** Lycopene is insoluble in water. By infusing the tomato powder in hot olive oil at 65°C-75°C.
- The oil acts as a solvent to "pull" the lycopene out of the tomato cells.
- This caused the oil infusion to turn orange-red in colour.

Ingredient	Solvent Used	Primary Active Constituent (Antioxidants)	Phase in Emulsion
Green Tea	Distilled water	Catechins / Caffeine	Aqueous phase
Rosemary	Olive oil	Carnosic acid	Oil phase
Tomato	Olive oil	Lycopene	Oil phase

SYNERGISTIC REACTIONS:

ANTIOXIDANT

1. Enhanced Radical Scavenging- Research indicates that combined extracts of green tea and rosemary exhibit significantly higher antioxidant

activity than when used individually, effectively terminating free radical chains.

2. Balancing UV Response- A blend of tomato and rosemary extracts (such as in the branded ingredient Lycoderm) has been shown to work



synergistically to inhibit inflammatory cytokines, specifically reducing the release of IL-6 more effectively than either compound alone.

3. Transcription System Activation- This specific combination (tomato and rosemary) synergistically activates the ARE/Nrf2 transcription systems, which are the body's internal mechanisms for balancing UV-induced oxidative

1. Green tea- It is rich in EGCG and it prevents UV -induced DNA damage (cyclobutane pyrimidine dimers) and reduces photoaging by protecting collagen and elastin from degrading enzymes.

2. Rosemary- Contains carnosic acid and rosmarinic acid, which prevent UV-induced damage in both human fibroblasts and keratinocytes

PHOTOPROTECTIVE MECHANISMS:

Direct UV Absorption- Tomato extract is rich in lycopene, a potent carotenoid with strong UV-radiation-absorbing properties that helps protect the skin from photo-induced damage.

SPF BOOSTING:

While these botanicals are not primary sunscreens, adding green tea extract to a formula can directly increase the SPF value in a dose-dependent manner.

DNA AND STRUCTURAL PROTECTION:

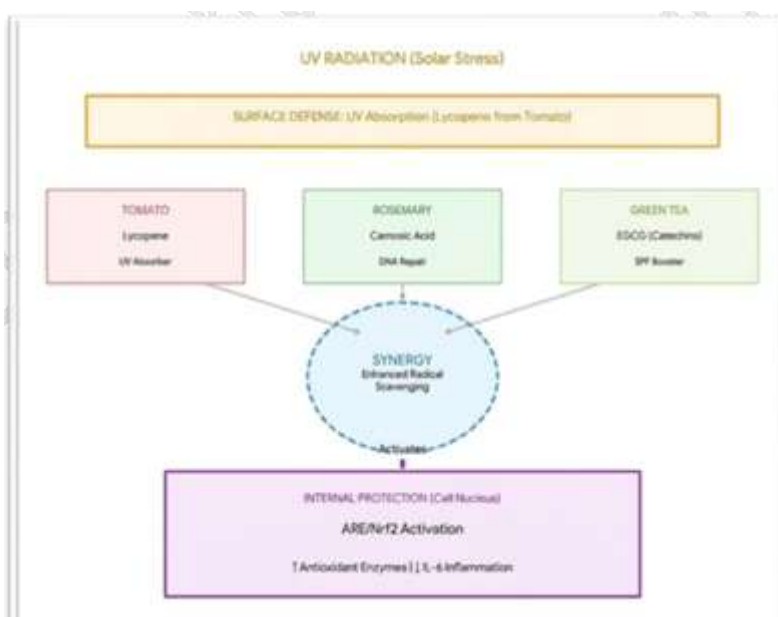


Figure 7: Synergistic Actions

FORMULATION TABLE:

Phase	Ingredients	Quantity (20g)	Concentration (%w/w)	Role in Formulation
Oil Phase	Infused olive oil (Rosemary and Tomato)	3.89g	19.47%	Emollient and Active Carrier
	Cetyl alcohol	0.79g	3.89%	Co-emulsifier and Thickener
	Stearic acid	0.58g	2.92%	Emulsifier Reactant
	Micronized Zinc oxide	0.78g	3.89%	Physical UV Filter

	Titanium dioxide	0.49g	2.43%	Physical UV (UVB) Filter
Aqueous Phase	Infused distilled water	11.68g	58.42%	Continuous Phase and Carrier
	Honey	0.97g	4.87%	Humectant
	Triethanolamine	0.20g	0.97%	Stabilizer
Cool Phase	Sodium benzoate	0.10g	0.49%	Preservative
	Ethylene diamine tetra acetic acid (EDTA)	0.04g	0.19%	Chelating Agent
	Menthol	0.49g	2.43%	Sensory Agent
	Citric acid	q.s	q.s	pH Adjuster
Total		20.00g	100.00%	

FORMULATION PROCEDURE:

Preparation of aqueous infusion-

1. 75g Distilled Water was heated to 85C.
2. 5g Green Tea powder was added and stirred vigorously.
3. The beaker was covered (to prevent evaporation) and was allowed to steep for 15 minutes.
4. The infusion was then filtered through a filter paper twice to avoid cloudiness or solid particles.
5. *Result:* 70-72g dark green, clear base.

Preparation of Oil infusion-

1. In a small heat -proof beaker, 25g Olive Oil was combined with 2.5g tomato powder and 2.5g rosemary powder.
2. The beaker was placed in a water bath (Bain-Marie) and heat to 70C.
3. The temperature was maintained for 30 minutes, stirring every 5 minutes.
4. Filtration: While still hot, the oil infusion was poured through a fine mesh strainer lined with a

high- grade coffee filter or double-layered muslin cloth.

5. The "sludge" was pressed with a spatula to recover as much oil as possible.
6. *Result:* 25g bright orange/red oil base.

Phase Preparation-

1. Prepare the Infused Bases (Tomato/Rosemary in oil and Green Tea in distilled water) as per the established extraction procedure mentioned above.
2. Oil phase- Combine the Infused Oil, Cetyl Alcohol, and Stearic Acid in a clean beaker. Heat the mixture to 75°C until all components are fully melted.
3. Gradually incorporate the Micronized Zinc Oxide (ZnO) and Titanium Dioxide (TiO₂) into the heated oil phase. Use a magnetic stirrer to ensure a homogenous mineral dispersion.
4. Aqueous phase- In a separate beaker, combine the Infused Water, Honey, and Triethanolamine (TEA). Heat this aqueous mixture to 75°C.





Figure 8: Preparation of Aqueous Phase

Emulsification Process-

1. Both the oil and aqueous phases were maintained between 72°C and 75°C before proceeding.
2. While continuously mixing the aqueous phase with a magnetic stirrer at 1000-1500 RPM, the oil phase slowly introduced.
3. The TEA reacted with the Stearic Acid to facilitate in-situ saponification, resulting in a pale skin toned, glossy emulsion. High-speed mixing for at least 3 minutes to stabilize the structure.

Cooling and Stabilization-

1. The mixing speed is slowly reduced as the formulation begins to cool.
2. Once the temperature reaches 40°C, Sodium Benzoate, EDTA and Menthol were added.
3. The preservative Sodium Benzoate is ineffective at a pH greater than 5.5. Using a digital pH meter to measure the pH; if necessary, the pH is adjusted to a range of 5.0 to 5.2 using a 10% Citric Acid solution.

Evaluation And Packaging-

1. The sunscreen was evaluated for its Organoleptic properties, Stability and Efficacy.
2. The cream was then filled into a suitable container and labelled accurately.

KEY INGREDIENT INTERACTIONS:

1. **The Emulsifier Pair (TEA + Stearic Acid)** - These are the most critical ingredients for the stability of the formulation. Triethanolamine (TEA) acts as a base that neutralizes the Stearic Acid to create Triethanolamine Stearate, a soap that prevents the separation oil and water.
2. **The Stabilizer (EDTA)** - Because we've used botanical infusions, metal ions present in the plant matter can cause the cream to discolour or go rancid. The EDTA "claws" these ions to keep the formula stable.
3. **The Physical Barrier (ZnO + TiO₂)** - These minerals need to be evenly dispersed in the Oil Phase during heating to ensure the final product is smooth and provides consistent UV protection.

APPLICATIONS:

1. Daily Wear 'City' Sunscreen-

Because the formulation uses a saponification reaction (TEA + Stearic Acid) to create a light, glossy emulsion, it is ideal for daily use under makeup or alone.

- **Pollution Defense:** The high concentration of Green Tea catechins provides a secondary layer of protection against urban pollutants and oxidative stress.

- **Cosmetic Elegance:** The "Warm Sand" hue acts as a natural tint, making it a "no-white-cast" option for people with medium skin tones.

2. Post-Procedure Soothing Cream-

The inclusion of Honey and Menthol makes this formulation suitable for skin that is slightly sensitized or "warm" to the touch.

- **Cooling Effect:** Menthol provides immediate relief from the heat of the sun.
- **Barrier Support:** The Cetyl Alcohol and Stearic Acid help rebuild the skin's lipid barrier, while Honey acts as a humectant to prevent trans epidermal water loss.

3. Anti-Photoaging Day Cream-

This formulation focuses heavily on Lycopene (from Tomato) and Carnosic Acid (from Rosemary), which are specifically targeted at preventing the breakdown of collagen.

- **Target:** Users concerned with fine lines and "sun spots" caused by long-term UV exposure.
- **Function:** The ZnO and TiO₂ block the rays, while the botanical extracts neutralize any free radicals that manage to penetrate the mineral shield.

4. Sports/Outdoor Activity Cream-

The Oil-in-Water (O/W) structure stabilized by TEA-Stearate is generally more resistant to "bleeding" into the eyes than simple oil-based lotions.

- **Stability:** The inclusion of EDTA and Sodium Benzoate ensures the product remains

microbially safe even if carried in a gym bag or outdoors in humid conditions.

EVALUATION TESTS:

A. Organoleptic and Physical Evaluation-

These tests ensure the product meets aesthetic standards and basic physical requirements.

1. Colour-

- The colour observed visually against a white background at room temperature.
- This was done in order to ensure consumer acceptance.
- *Result-* The colour can be described as *Peach or Skin Tone*.

2. Odour-

- A slight amount of formulation was withdrawn and sniffed
- *Result-* The cream was found to have a *Menthol like Fragrance*.

3. Consistency-

- Tested by applying the formulation on skin so as to check for smoothness or grittiness.
- *Result-* The cream was found to be *Smooth with No Grittiness*.



Figure 11: Consistency Test

Test	Result
Colour	Peach / Skin tone
Odour	Menthol like
Consistency	Smooth

B. Physicochemical Testing-

1. pH Determination-

- 1g of cream was dissolved in 100ml of distilled water.
- The pH was determined using a digital pH meter calibrated with buffer solutions.
- Result-* The pH was found to be 5.2-5.5.

2. Water Solubility-

- A small amount of formulation was shaken with distilled water in a test tube to observe miscibility.
- An oil in water (O/W) emulsion should be easily miscible in water.
- Result-* The cream is Water Soluble.

3. Viscosity-

- Viscosity was measured using Brookfield Viscometer using spindle No. 63 at 10 RPM.
- Result-* Viscosity was found to be 695-760 cP

4. Spreadability-

- Measured by the "Parallel Plate" method.
- A known weight was placed on the glass slide covering the sample, and the diameter of the spread is measured after a set time.

$$S = \frac{M \times L}{T}$$

- Where, S= Spreadability, M= Weight, L= Diameter and T= Time

- Calculation-

$$S = \frac{M \times L}{T}$$

$$S = \frac{1 \times 2.5}{50}$$

$$S = 0.05 \text{ cm/s}$$

- Result-* Spreadability of the formulation was found to be 0.05 cm/s

Test	Result
pH	5.2-5.5
Water Solubility	Soluble
Viscosity	695-760 cP
Spreadability	0.05 m/s

C. Stability and Performance Testing-

1. Freeze-Thaw Stability Test-

- This test simulates transport and storage stress. If the emulsion breaks i.e. undergoes phase separation, the sunscreen filters might not be distributed evenly.
- The sample was subjected to extreme temperature fluctuations- 24 hours at -10°C followed by 24 hours at 40°C.
- Result-* No cracking or phase separation.





Figure 14: Before Freeze Thaw



Figure 15: After Freeze Thaw

2. Theoretical SPF (In Vitro)-

- 1g of sample was dissolved in 100ml of ethanol (1% \ w/v).
- A 5ml of the liquid was diluted to 50ml (0.1% w/v final).^[22]
- Absorbance was measured in the UV-B range (290–320 nm) at 5 nm intervals.

Observations-

Wavelength (λ)	EE×I (λ)	Absorbance (A)	EE×I×A
290	0.0150	1.350	0.02025
295	0.0817	1.425	0.11642
300	0.2874	1.510	0.43397
305	0.3278	1.580	0.51792
310	0.1864	1.550	0.28892
315	0.0839	1.320	0.11075
320	0.0180	1.260	0.02268
Sum (Σ)	1.000		1.51091

- Formula ^[19]-

$$SPF = CF \times \sum_{290}^{320} EE \times I \times A$$

Where, CF = 10, EE = Erythral effect, I = Solar intensity

- Calculation-

$$SPF = CF \times \sum_{290}^{320} EE \times I \times A$$

$$SPF = 10 \times 1.51091$$

$$SPF = 15.10$$

- Result-* Theoretical Sun Protection Factor (SPF) = 15.10

3. Franz Diffusion Cell (Skin Permeation) ^[20]-

- This test is performed in order to ensure that the antioxidants penetrate the stratum corneum but the UV filters remain on the surface.
- A specific amount of sunscreen is applied on an egg membrane and mounted in a Franz cell.
- The receptor compartment contained a phosphate buffer with pH 5.5.
- Calibration Curve-

Before the diffusion test, a calibration curve must be established a standard curve at 320 nm.

$$R^2 = 0.999\$$$

Concentration ($\mu\text{g/mL}$)	Absorbance (at 320 nm)
0	0.000
2	0.142
4	0.285
6	0.428
8	0.572
10	0.715

Linear Regression Equation: $y = 0.0715x$

(Where y = Absorbance and x = Concentration)

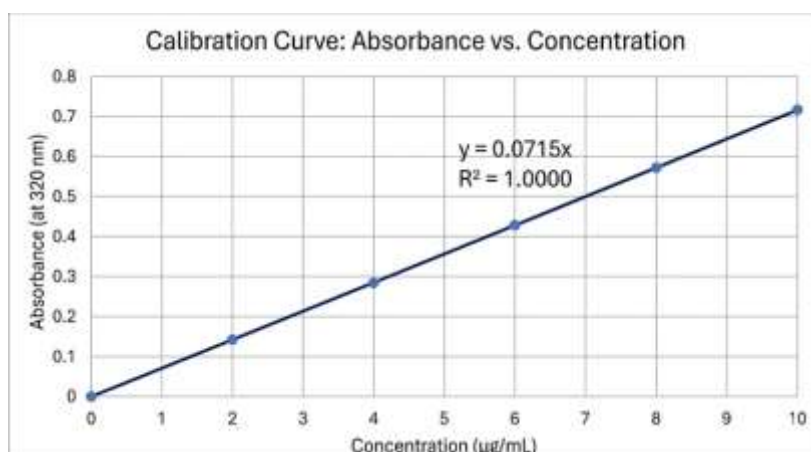


Figure 18: Calibration Curve

- Observation-

Media- Phosphate Buffer (pH 5.5)

Now using the equation $x=y/0.0715$ concentration is calculated from absorbance. We assume the receptor compartment volume is 10 mL and the total drug loaded in the donor is 1000 μg (1 mg).

Temperature- $37^{\circ}\text{C} \pm 0.5^{\circ}\text{C}$

λ_{max} - **320 nm** (highest absorbance in the SPF table)

Time (min)	Absorbance (at λ_{max})	Concentration ($\mu\text{g/mL}$)	Amount Permeated (mg)	Cumulative % Release
0	0.000	0.00	0.00	0.00%
15	0.112	1.57	15.7	1.57%
30	0.355	4.97	49.7	4.97%
45	0.640	8.95	89.5	8.95%
60	0.895	12.52	125.2	12.52%

- **Result-** Permeation across the egg membrane showed a cumulative drug release of 12.52% (125.2 μg) over a period of 60 minutes.

The calibration curve showed excellent linearity with an equation of $y = 0.0715x$ and $R^2 = 0.999$.

Test	Result
Freeze-Thaw Stability Test	No cracking or phase separation
In-Vitro SPF Test	15.10
Franz Diffusion Test	Cumulative Drug Release = 12.52% (125.2 μg).



A. Safety Testing [21]-

1. Human Repeated Insult Patch Test (HRIPT)-

- This test was performed on a single volunteer in order to ensure complete safety for use.
- This is crucial for claiming "Dermatologically Tested".
- The sunscreen was applied to a patch on the volar forearm.
- The patch was left on for 24 hours and then removed and observed for redness / oedema on the skin.
- This test was repeated over a period of 2 weeks (Induction phase) in order to observe for any late onset reactions.
- The following irritation scoring scale "Draize Scale" was used to determine the irritation and sensitization potential of our formulation.

Score	Clinical Observation	Definition
0	No visible reaction	Skin appears normal; no erythema or oedema.
0.5	Barely perceptible	Faint, minimal, or questionable erythema (redness).
1	Mild	Slight but confluent erythema; distinct pinkness.
2	Moderate	Moderate erythema; definite redness, possibly accompanied by mild oedema (swelling).
3	Marked	Severe erythema (deep red) with pronounced oedema.
4	Severe	Deep red erythema with severe oedema, possible vesiculation (blistering), or ulceration.

Result- Zero irritation score (0) was observed.

RESULT:

The following table summarizes the comprehensive evaluation results of the formulated herbal sunscreen:

Category	Test Parameter	Observation / Result
Organoleptic	Colour	Peach or Skin Tone
	Odour	Menthol-like fragrance
	Consistency	Smooth with no grittiness
	pH	5.2 – 5.5
Physicochemical	Water Solubility	Soluble
	Viscosity	695 – 760 cP
	Spreadability	0.05 cm/s
Stability	Freeze-Thaw Test	No cracking or phase separation
Performance	In-Vitro SPF	15.10 (Theoretical)
	Franz Diffusion	12.52% (125.2\$ µg) cumulative release over 60 min
	Steady-State Flux	12.13 µg/min
Safety	Human Patch Test	Zero irritation score (0) on Draize Scale

CONCLUSION:

- Successful Formulation:** The study successfully developed an oil-in-water (O/W) emulsion-based herbal sunscreen utilizing synergistic extracts of Green Tea, Rosemary, and Tomato.
- Effective Protection:** The formulation achieved a theoretical SPF of 15.10, providing a biological "Botanical Barrier" through both physical filters and antioxidant-rich herbal extracts.
- High Stability:** The product demonstrated excellent stability with no phase separation



during extreme freeze-thaw cycles and maintained an ideal skin-compatible pH.

4. **Consumer Appeal:** Evaluation showed good spreadability, smooth consistency, and a "no-white cast" peach tint suitable for daily use.
5. **Safety Assured:** Human safety testing (HRIPT) confirmed the sunscreen is non-irritating and safe for topical skin application.

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