Development and Evaluation of Suncream Cream for Plumeria Rubra

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Abstract—**Regular exposure to solar ultraviolet radiation causes severe skin damage, making photoprotection essential. Due to the adverse health and environmental effects linked with synthetic UV filters, cosmetic research is shifting toward sustainable botanical alternatives. This study aimed to develop and evaluate an oil-in-water (O/W) herbal sunscreen cream utilizing the bioactive flower extract of Plumeria rubra. Fresh flowers were authenticated, dried, and extracted using absolute ethanol. Pre-formulation characterization of four distinctive powder mesh fractions (A, B, C, and D) was conducted to evaluate micromeritic parameters and solvent solubility profiles. Four cream batches were compounded via the slab technique by varying the extract concentrations alongside structural excipients. The formulations underwent comprehensive post-evaluation, assessing color, odor, texture, phase separation, pH, viscosity, spreadability, greasiness, washability, skin irritancy, and in-vitro Sun Protection Factor (SPF). Pre-formulation screening revealed that particle size fractions around mesh 60# (Sieve B) possessed optimal micromeritic flow, excellent compressibility, and superior dissolution properties. Among the compounded batches, formulation F2 incorporating 2.0% w/w P. rubra extract, emerged as the optimized batch. It demonstrated an off-white color, a smooth and homogeneous texture, a stable skin-compatible pH of 6.5, balanced viscosity (837.1 cps), and excellent spreadability without phase separation, greasiness, or skin irritation. Biologically, F2 delivered moderate sun protection with the highest in-vitro SPF value of 18. Consequently, Plumeria rubra flower extract represents a safe, eco-friendly, and effective natural alternative to synthetic chemical filters in modern skincare.**

Index Terms—**Plumeria rubra, Sunscreen Cream, Oil-in-Water Emulsion, In-vitro SPF, Phytochemicals, Photoprotection.**

I. INTRODUCTION

The human skin is the largest organ of the body and functions as the primary protective barrier against environmental insults, including microbial invasion, pollution, and ultraviolet (UV) radiation (1). However, regular exposure to solar ultraviolet radiation causes severe cutaneous disruptions (2). Sunlight hitting the Earth's surface contains ultraviolet A (UVA: 320–400 nm) and ultraviolet B (UVB: 280–320 nm) wavelengths, while ultraviolet C (UVC: 100–290 nm) is effectively filtered by the stratospheric ozone layer (3). UVA rays penetrate deeply into the dermal layers of the skin, triggering long-term oxidative stress, generation of reactive oxygen species (ROS), wrinkling, structural DNA breaks, and photoaging (4). Conversely, UVB rays are mostly absorbed by the superficial epidermis, acting as the major driver behind sunburn, acute erythema, skin inflammation, and photocarcinogenesis (5).

To control these structural distortions, topical sunscreen preparations are formulated to absorb, scatter, or reflect incoming photons before they harm cutaneous cells (6). Conventional formulations incorporate physical blockers (e.g., Titanium Dioxide, Zinc Oxide) or chemical UV filters (e.g., avobenzone, oxybenzone) (7). Despite their performance, synthetic chemicals are linked with systemic sensitization, endocrine disruption, contact allergies, and environmental ecotoxicity (8). Consequently, contemporary cosmetic research is shifting toward sustainable, bio-based alternatives rich in photoprotective polyphenols (9).

Plumeria rubra Linn. (commonly termed Frangipani or Temple Tree), a member of the Apocynaceae family, is a small deciduous tree indigenous to tropical zones (10). Extensively recognized in traditional healing systems for mitigating skin wounds, ulcers, and inflammatory

diseases, its secondary metabolic profile is rich in bioactive components [11]. Plumeria rubra flowers possess high concentrations of flavonoids (such as rutin and quercetin), iridoids (plumericin and plumieride), phenolic acids (chlorogenic acid and p-coumaric acid), terpenoids, and alkaloids [12].

Fig 1: Plumeria rubra

These naturally occurring secondary metabolites act via a dual-action mechanism: they strongly absorb UV photons due to conjugated double-bond networks, and concurrently function as powerful radical scavengers that neutralize radiation-induced free radicals [13]. Emulsified oil-in-water (O/W) bases are an ideal delivery mechanism for these botanical extracts because they ensure uniform cutaneous coverage, possess excellent spreadability, remain non-greasy, and provide continuous hydration [14].

This investigation was designed to extract photoprotective fractions from authenticated flowers of Plumeria rubra, systematically carry out pre-formulation evaluations, engineer a stable topical O/W suncream cream, and evaluate its physicochemical parameters alongside its in-vitro Sun Protection Factor (SPF) [15].

II. MATERIAL AND METHODS

2.1 Materials and Botanical Authentication

Fresh flowers of Plumeria rubra L. were collected locally [16]. The raw botanical material was submitted to the Plant Taxonomy Research Laboratory, Department of Botany, Nanded Education Society's Science College, Nanded, where it was identified and officially authenticated (Certificate Date: 19/02/2026) (16). All key chemical excipients utilized for the compounding phase including stearic acid, cetyl alcohol, liquid paraffin, glycerin, borax, beeswax, methyl paraben, propyl paraben, and rose oil were of analytical cosmetic grade [17].

2.2 Functional Role of Ingredients

The functional assignments of the raw plant components and active chemical excipients within the sunscreen matrix are summarized below:

Table No. 1 Role of Ingredients [16]

Ingredient	One-line Role
Plumeria rubra Extract	Active herbal ingredient providing antioxidant and photoprotective activity.
Stearic acid	Thickening agent and emulsifier that improves cream consistency.
Cetyl alcohol	Emollient and co-emulsifier that enhances texture and stability.
Liquid paraffin	Emollient that prevents moisture loss and softens the skin.
Glycerine	Humectant that retains moisture and hydrates the skin.
Rose oil	Fragrance and skin-conditioning agent.
Borax	Emulsifying agent that stabilizes the oil-in-water cream.
Bees wax	Stiffening agent that increases consistency and forms a protective barrier.
Methyl paraben	Preservative that inhibits microbial growth.
Propyl paraben	Preservative effective against fungi and molds.
Distilled water	Vehicle that dissolves water-soluble ingredients and makes up the final volume.

2.3 Extraction Processing

The fresh flowers were washed thoroughly under distilled water to remove particulate impurities and dried inside a hot air oven [18]. Once completely dried, the floral tissues were pulverized into a fine powder utilizing a laboratory grinder (18). For the extraction phase, 0.5 g of the processed P. rubra powder was combined with 10 mL of absolute ethanol inside a volumetric flask [19].

The mixture was agitated for several hours using a laboratory stirrer, subsequently heated on a controlled water bath at 80–100°C, and concentrated down to a volume of 5 mL [19]. The crude solution was filtered through a clean muslin cloth to isolate a clarified, dark

phytochemical extract, which was then stored for formulation batch runs [19].

Fig 2: Extract of P. rubra powder

2.4 Pre-formulation Evaluation Methodology

a) General Appearance

The isolated botanical powder fractions were subjected to qualitative visual and sensory assessments to note their color, odor, and taste profile [20].

b) Bulk Density

A precisely weighed mass (M) of the dried plant powder was gently introduced into a clean 100 mL graduated measuring cylinder [21]. The initial loose bulk volume (V_0) occupied by the powder was recorded [21]. The calculation was performed using the standard formula [21]:

c) Tapped Density

The graduated cylinder containing the weighed powder was mounted onto a mechanical tap density tester and subjected to fixed tapping intervals (100–300 taps) until a plateau volume (V_f) was reached [21]. The tapped density value was determined via the formula [21]:

d) Carr's Compressibility Index

The percentage compressibility factor of the crude botanical matrix was derived to assess interparticulate behaviors using the index formula [22]:

e) Hausner's Ratio

The structural friction index within the sample was determined by evaluating the ratio of tapped density over bulk density [22]:

f) Angle of Repose (\theta)

The internal friction and loose flow patterns of the plant powder fractions were evaluated utilizing the fixed funnel method [23]. The height (h) and radius (r) of the symmetric conical pile generated by the free-flowing powder were measured [23]. The internal angle was calculated via the inverse tangent relationship [23]:

Fig 3: Angle of repose

g) Moisture Content (Loss on Drying)

A sample mass of 1.5 g of the botanical material was distributed across a dry porcelain dish and positioned inside an oven held at 105°C [24]. The sample was dried until it reached a constant weight [24]. The total moisture content percentage was calculated as follows [24]:

h) Total Ash Value

To determine the inorganic residue profile and confirm material purity, 2.0 g of dried powder was transferred to a tared silica crucible (x) [25]. The sample weight with the drug was recorded (y) and ignited over a burner flame until completely carbonized [25]. The crucible was cooled to room temperature and weighed to determine the final ash weight (z) [25]. The percentage of total inorganic ash was calculated using the formula [25]:

Fig 4 Ash value

i) Solvent Solubility Profiles

The relative solubility patterns of the different sieved powder populations were screened in three distinct solvents: Distilled Water (H_2O), 0.1 N Hydrochloric Acid (HCl), and 0.1 N Sodium Hydroxide (NaOH) [26].

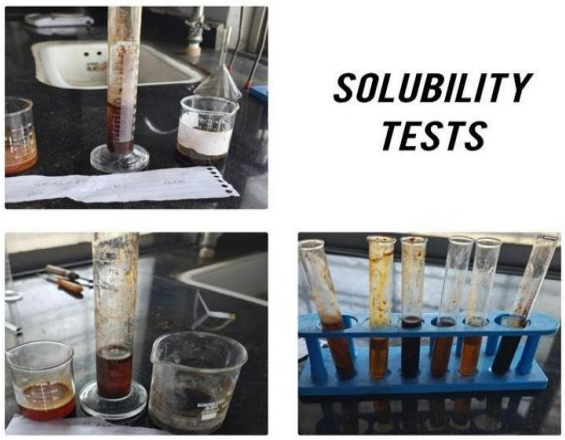

Fig 5: Solubility study

III. EXPERIMENTAL WORK

3.1 Formulation of Suncream Creams

Four distinct herbal oil-in-water (O/W) emulsion batches (designated F1, F2, F3 and F4) were developed by selectively varying the active Plumeria rubra floral extract quantities from 1.0 g to 4.0 g while modifying structural consistency agents like stearic acid and cetyl alcohol [27]. The comprehensive quantitative compounding matrix is presented below:

Table No. 2: Formulation Matrix [27]

Sr. No.	Ingredients	F1 (% w/w)	F2 (% w/w)	F3 (% w/w)	F4 (% w/w)
1	Plumeria rubra Extract	1	2	3	4
2	Stearic acid	3	3	4	4
3	Cetyl alcohol	2	2	3	3
4	Liquid paraffin	5	5	5	5
5	Glycerine	4	4	4	4
6	Rose oil	1	1	1	1
7	Borax	0.08	0.08	0.08	0.08
8	Bees wax	1.6	1.6	1.6	1.6
9	Methyl paraben	0.20	0.20	0.20	0.20
10	Propyl paraben	0.02	0.02	0.02	0.02
11	Distilled water	q.s. to 100	q.s. to 100	q.s. to 100	q.s. to 100

3.2 Compounding Methodology (Slab Technique)

1. Oil Phase Preparation: Liquid paraffin, beeswax, stearic acid, and cetyl alcohol were combined in a borosilicate glass beaker and melted under steady heating at 75°C [28].

Fig 6: Oil Phase

2. Aqueous Phase Preparation: In a separate beaker, borax and the methyl/propyl paraben preservatives were dissolved in a quantity sufficient of distilled water and heated to 75°C to form a clear solution [28].

Fig 7: Aqueous Phase

3. Primary Emulsification: The heated aqueous phase was added slowly into the hot oil phase under continuous, high-shear stirring to induce core phase inversion and form the emulsion base (28).

Fig 8: Emulsification

4. Active Component Integration: The concentrated ethanolic extract of Plumeria rubra was systematically incorporated into the cooling base under continuous agitation [29]. Rose oil was subsequently added to impart a pleasant floral scent [29].

5. Homogenization: The resulting cream was transferred onto a clean ointment slab [30]. Utilizing a spatula, it was manipulated in a geometric motion with the progressive addition of drops of distilled water where necessary [30]. This mechanical shearing process yielded a smooth, uniform cosmetic texture [30].

Fig 9: Suncream formation

3.3 Post Evaluation Test

1. Color [31]

The color of the cream formulation was evaluated by visual inspection under normal daylight using a white background. The appearance and uniformity of the color were observed and recorded.

2.Odor [31]

The odor of the formulation was evaluated by smelling a small quantity of the cream immediately after preparation. The characteristic odor and any unpleasant smell were noted.

3.Texture [31]

The texture of the cream was evaluated by rubbing a small quantity between the fingertips. The formulation was examined for smoothness, homogeneity, consistency, and the absence of grittiness.

4. Phase Separation [31]

The prepared cream formulations were visually examined for any signs of phase separation during storage at room temperature and throughout the stability study. The formulations were considered stable if no separation of oil and aqueous phases was observed.

5. pH [32]

The pH of the cream was determined by dispersing 1 g of the formulation in 9 mL of distilled water. The dispersion was allowed to equilibrate, and the pH was measured using a calibrated digital pH meter at room temperature.

Fig 10: pH determination

6.Viscosity [32]

The viscosity of the cream was measured using a Brookfield Viscometer fitted with a suitable spindle at 10 rpm and maintained at 25 ± 2°C. The viscosity was recorded in centipoise (cps).

Fig 11: Viscosity determination

7.Spreadability [33]

Spreadability was determined by placing approximately 1 g of cream between two glass slides. A standard weight was placed on the upper slide to obtain a uniform film, and the time required for the upper slide to move a fixed distance under an applied weight was recorded. Spreadability was calculated using the formula $S = M \times L / T$, where M is the applied weight, L is the distance moved, and T is the time taken.

8.Greasiness [34]

Greasiness was evaluated by applying a small amount of cream to the skin and gently rubbing it. The formulation was observed for the presence of oily residue and classified as greasy, non-greasy, or slightly greasy based on visual appearance and touch.

9. Skin Irritancy [35]

Skin irritation was evaluated by applying a small amount of the formulation to a limited area of healthy skin. The application site was observed after 24 hours for any signs of erythema, itching, edema, or irritation.

Fig 12: Irritancy test

10. Washability [34]

Washability was determined by applying the cream to the skin and washing it with tap water without using soap. The ease of removal was observed and recorded as easily washable, washable, moderately washable, or difficult to wash.

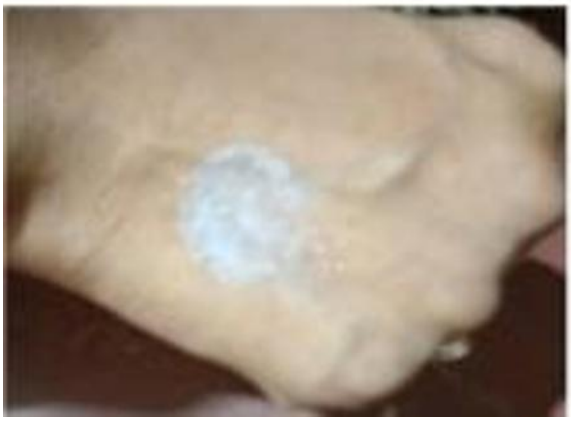

Fig 13: Washability test

11. In-vitro SPF [35]

The in-vitro Sun Protection Factor (SPF) was determined using UV-Visible spectrophotometry. A known quantity of the cream was dissolved in ethanol, filtered, and the absorbance was measured between 290 and 320 nm at 5 nm intervals. The SPF value was calculated using the Mansur equation.

IV. RESULTS AND DISCUSSION

4.1 Pre-formulation Evaluation

The micromeritic metrics across four distinctive mesh fractions (A, B, C, and D) are reported below:

Table No. 3: Pre-formulation Characterization of Powder Fractions

Sieve No.	Bulk Density (g/cm³)	Tapped Density (g/cm³)	Carr's Index (%)	Hausner Ratio	Angle of Repose (°)	Ash Value (%)	Interpretation
A (44#)	0.33	0.40	17.20	1.22	28.0	71.0	Good flowability with acceptable compressibility; lowest ash value among samples.
B (60#)	0.38	0.42	9.42	1.10	38.0	73.0	Excellent compressibility and good flow properties; considered the best-performing powder.
C (80#)	0.35	0.46	23.91	1.31	40.0	74.0	Fair to passable flow with poor compressibility due to finer particles.

D (100#)	0.33	0.36	23.09	1.30	42.0	80.0	Poor flowability and compressibility; highest ash value, indicating greater inorganic residue.

Table No. 4: Solvent Solubility Matrix

Sieve No. (#)	Water (%)	0.1 N HCl (%)	0.1 N NaOH (%)	Observation
A (44)	17.50	9.33	13.00	Slightly soluble
B (60)	11.00	18.00	11.00	Soluble
C (80)	8.00	5.00	12.00	Soluble
D (100)	2.00	4.00	8.00	Soluble

Table No. 5: Comprehensive Physicochemical Profile of the Formulations

Parameter	F1	F2	F3	F4
Color	Off-White	Light Yellow	Yellowish	Dark Yellowish
Odor	Floral	Characteristic	Characteristic	Intense Floral
Texture	Smooth	Smooth, Homogeneous	Slightly Thick	Coarse
Phase Separation	Not Observed	Not Observed	Not Observed	Not Observed
pH	6.2	6.5	6.7	6.8
Viscosity (10 rpm)	821.5 cps	837.1 cps	854.2 cps	889.0 cps
Spreadability (g·cm/s)	4.1	5.2	3.9	3.2
Greasiness	Oily Residue	Non-Greasy	Non-Greasy	Heavy/Greasy
Skin Irritancy	Mild Sign	No Irritancy	Mild Sign	Irritation Sign
Washability	Moderately Washable	Easily Washable	Washable	Difficult to Wash
In-vitro SPF	12	18	17	15

V. DISCUSSION

The pre-formulation assessment of Plumeria rubra powder fractions established a critical correlation between particle size distribution and structural performance. Sieve No. B (60#) exhibited the most favorable micromeritic profile, demonstrating a low Carr's index, an ideal Hausner ratio (1.10), and excellent solubility across all screened solvents. In contrast, the finer particle fractions from Sieve No. C and D presented poor flowability, passable compressibility, and elevated total ash values, indicating a higher concentration of inorganic residues. These metrics confirmed that the 60# mesh fraction ensures optimal blending uniformity and physical stability, making it uniquely suited for continuous, uniform incorporation into the emulsified oil-in-water cosmetic base.

The comprehensive post-evaluation profile highlighted distinct variations in the physicochemical attributes and biological efficacy of the formulations based on extract concentrations. While higher extract concentrations in batches F3 and F4 increased structural viscosity, they inadvertently resulted in coarse textures, greasy dermal residues, poor washability, and noticeable skin irritation signs. Conversely, formulation F2 emerged as the optimized batch, striking an ideal balance with a smooth, homogeneous texture, easy washability, and a skin-compatible pH of 6.5. Furthermore, F2 recorded the highest in-vitro SPF value of 18. This enhanced photoprotective performance is attributed to the optimal dispersion of native flavonoids and phenolic acids, which effectively absorb UV photons and neutralize radiation-induced free radicals without disrupting the emulsion matrix.

VI. CONCLUSIONS

This study demonstrates the successful development of a stable, high-performance herbal suncream cream utilizing the photoprotective flower extract of Plumeria rubra pre-formulation screening confirmed that particle size fractions around 60\# possess optimal micromeritic flow and dissolution properties, allowing for seamless integration into an oil-in-water (O/W) emulsion base.

Among the evaluated batches, formulation F3 of the active extract exhibited optimal physicochemical properties, including an ideal skin-compatible pH of 6.5, a balanced viscosity of 837.1 cps, excellent spreadability nd no skin irritancy.

Biologically, formulation F_2 delivered moderate sun protection with an in-vitro SPF value of 18, driven by the UV-absorbing and antioxidant capabilities of its native flavonoids and phenolic compounds. The formulation also maintained excellent physical stability under accelerated thermal stress. These findings indicate that Plumeria rubra flower extract holds significant potential as a safe, eco-friendly, and effective natural alternative to synthetic chemical UV filters in modern cosmetic skincare

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