STM JOURNALS

Recent Trends in
Cosmetics

ISSN: 3048-8532
Volume 2, Issue 2, 2025
July–December
DOI (Journal): 10.37591/RTC

https://journals.stmjournals.com/rtc/

Research RTC

# Development and Evaluation of a Cost-Effective UV-Protective Cream Containing Para-Aminobenzoic Acid and Aloe Vera for Indian Climatic Conditions

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**_Abstract_**

*The increasing incidence of ultraviolet radiation-induced skin disorders has heightened the demand for effective, affordable photoprotective agents, especially in countries with high sun exposure such as India. This study aimed to develop a cost-effective and efficient UV-B protective cream formulation suitable for populations in Indian latitudes. Para-aminobenzoic acid (PABA) was selected as the primary sunscreening agent due to its high UV-B absorption efficiency, low toxicity, and affordability compared with many synthetic and imported commercial sunscreens. The study was conducted in two main phases: (i) formulation and optimization of cream bases (C1–C6) and (ii) evaluation of the developed formulations for sensory, physicochemical, and photoprotective properties. Base optimization identified formulation C3 as the most suitable candidate for UV-B protection. Six creams containing varying concentrations of PABA (1%–3%) and aloe vera (0% or 10%) were prepared using the phase inversion method. All formulations were evaluated for pH, emulsion type, acid and saponification values, extrudibility, spreadability, viscosity, and drug content. Both in-vitro and in-vivo sun protection factor (SPF) values were determined, alongside stability assessments using freeze–thaw cycles. Results indicated that all creams complied with pharmacopeial standards, and SPF values increased proportionally with PABA concentration and aloe vera content. The formulation containing 2% PABA and 10% aloe vera (C5) demonstrated optimal balance between sensory qualities, SPF efficacy (in-vitro SPF: 6.7; in-vivo SPF: 6.2), and stability. The study highlights the potential of cost-effective sunscreen formulations tailored to Indian climatic conditions, providing a practical solution for large-scale public use in low- and middle-income populations.*

**Keywords:** UV-shielding, para-aminobenzoic acid, aloe vera, topical formulation, SPF evaluation, photoprotection

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Received Date: August 12, 2025
Accepted Date: September 21, 2025
Published Date: December 17, 2025

**Citation:** Maya Sharma, Ranu Sharma, Hemlata Salvi, P.K. Choudhury. Development and Evaluation of a Cost-Effective UV-Protective Cream Containing Para-Aminobenzoic Acid and Aloe Vera for Indian Climatic Conditions. Recent Trends in Cosmetics. 2025; 2(2): 7–18p.

## INTRODUCTION

### Background

Ultraviolet (UV) radiation is a component of solar energy that significantly affects human skin health. While moderate sun exposure plays a beneficial role in vitamin D synthesis, prolonged or unprotected exposure is associated with a spectrum of acute and chronic dermatological conditions, including erythema, sunburn, photoaging, and skin malignancies such as basal cell carcinoma, squamous cell carcinoma, and malignant melanoma [1–5]. UV radiation is broadly classified into UVA (320–400 nm), UVB (290–320 nm), and UVC (<290 nm), with UVB being a primary contributor to erythema and skin carcinogenesis.

**Indian Climatic Relevance**

India's geographical location (latitudes 8°N–37°N) subjects its population to high levels of year-round UV exposure, particularly UVB intensity, which peaks during summer months [2]. Outdoor laborers, agricultural workers, and individuals with hypopigmentation disorders, such as albinism or vitiligo, are especially vulnerable. Furthermore, public awareness regarding photoprotection remains limited, and the relatively high cost of imported sunscreen products restricts their accessibility to economically disadvantaged populations.

**Sunscreens and Sunblocks**

Topical photoprotective products are broadly categorized as sunscreens and sunblocks. Sunblocks are opaque formulations that physically reflect or scatter UV radiation, commonly containing zinc oxide or titanium dioxide. Sunscreens, on the other hand, are transparent preparations containing chemical absorbers, such as PABA, oxybenzone, or cinnamates, which absorb specific UV wavelengths [6–8]. Although broad-spectrum formulations are ideal, targeted UVB protection remains crucial for populations at risk of sunburn-related damage.

**Choice of Para-Aminobenzoic Acid (PABA)**

PABA is a well-established UVB absorber with a λmax of approximately 288 nm, making it highly effective in blocking erythemogenic wavelengths. It offers several advantages: affordability, low toxicity, high stability, and proven efficacy in preventing UVB-induced erythema [9–13]. Despite declining popularity in certain Western markets due to sensitization concerns in rare cases, PABA remains widely accepted in developing countries where cost-effectiveness is a priority.

**Role of Aloe Vera**

Aloe vera gel is valued for its soothing, moisturizing, and antioxidant properties. It contains polysaccharides, vitamins, and phenolic compounds that can contribute to skin hydration and potentially enhance photoprotection [14–17]. The synergistic use of aloe vera with PABA could provide additional benefits, including the reduction of UV-induced inflammation and improved cosmetic acceptability of the cream.

**Study Objectives**

This study was designed to develop, optimize, and evaluate a UVB-protective cream containing PABA as the primary sunscreening agent, with and without aloe vera. The specific objectives were:

- To prepare cream formulations using the phase inversion method with varying concentrations of PABA and aloe vera.
- To evaluate sensory, physicochemical, and stability characteristics of the formulations.
- To determine in vitro and in vivo SPF values and assess formulation performance under simulated environmental stress conditions.

## MATERIALS AND METHODS

**Materials**

PABA (analytical grade) was procured from a certified supplier. Aloe vera gel was obtained from fresh Aloe barbadensis Miller leaves and standardized for polysaccharide content. Other excipients included sesame oil, almond oil, cetyl alcohol, stearic acid, sorbitan stearate, sorbitan monooleate, propylene glycol, glycerin, and essential oils. All reagents and solvents were of analytical grade and used as received.

**Formulation Design**

Six formulations (C1–C6) were prepared, differing in PABA concentration (1%–3%) and aloe vera content (0% or 10%). A preliminary base optimization study determined C3 as the most suitable emulsion base for photoprotective purposes. Formulation compositions were chosen to balance photoprotection, sensory acceptability, and stability.

**Preparation Method**

The creams were prepared using a phase inversion technique (Table 1).

- *Oil Phase Preparation:* Sesame oil, almond oil, cetyl alcohol, stearic acid, sorbitan stearate, and sorbitan monooleate were weighed and heated to 65°C–75°C under gentle stirring.
- *Aqueous Phase Incorporation:* Preheated deionized water (72°C) was gradually added to the oil phase at a rate of 30 ml/min while stirring at 110 rpm.
- *Active Incorporation:* Once the emulsion temperature reached 50°C, PABA (dissolved in propylene glycol) was added to the mixture, triggering phase inversion.
- *Cooling and Final Additions:* Upon cooling to below 40°C, aloe vera gel, glycerin, and essential oils were incorporated.
- *Homogenization:* The mixture was homogenized to ensure uniform distribution of active ingredients.

**Table 1.** Composition of cream.

| **Ingredients (gm)** | **C1** | **C2** | **C3** | **C4** | **C5** | **C6** |
|---|---|---|---|---|---|---|
| Cetyl alcohol | 3.5 | 3.5 | 3.5 | 3.5 | 3.5 | 3.5 |
| Stearic acid | 4.75 | 4.75 | 4.75 | 4.75 | 4.75 | 4.75 |
| Glycerin | 3.5 | 3.5 | 3.5 | 3.5 | 3.5 | 3.5 |
| Propylene glycol | 4.0 | 7.0 | 10.0 | 4.0 | 7.0 | 10.0 |
| Sesame oil | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 |
| Almond oil | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 |
| Honey | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 |
| Jojoba oil | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 |
| Tea tree oil | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 |
| Span 60 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 |
| Tween 80 | 1.75 | 1.75 | 1.75 | 1.75 | 1.75 | 1.75 |
| PABA | 1 | 2 | 3 | 1 | 2 | 3 |
| Aloe vera | – | – | – | 10 | 10 | 10 |
| Deionized water (ml) | q.s | q.s | q.s | q.s | q.s | q.s |

**Evaluation of Formulations**

***Sensory (Psychometric) Evaluation***

A trained panel of 18 volunteers (6 males, 12 females) evaluated appearance, spreadability, after-feel, and residue on a five-point hedonic scale.

***Physicochemical Properties***

- *pH:* Measured in a 1:10 aqueous dilution at 25°C.
- *Dye test:* To confirm emulsion type (oil-in-water).
- *Acid and saponification values:* Determined per Indian Pharmacopoeia.
- *Extrudibility:* Time to extrude a 1 cm ribbon under a 1 kg load.
- *Spreadability:* Time required to separate two glass slides under a specified weight.
- *Viscosity:* Measured using a Brookfield viscometer (spindle no. 6, 10 rpm).
- *Drug content:* PABA concentration determined spectrophotometrically at 288 nm.

***SPF Determination***

- *In-vitro SPF:* Calculated using the Mansur and Garcia method, measuring absorbance between 290–320 nm at 5 nm intervals.
- *In-vivo SPF:* Determined by comparing minimum erythemal dose (MED) values for protected versus unprotected skin on healthy volunteers.

**Stability Testing**

Formulations underwent five freeze–thaw cycles between 25°C and −5°C. Post-cycle, samples were examined for phase separation, color change, viscosity alteration, and pH variation.

## RESULTS AND DISCUSSION

### Characterization of PABA

The physicochemical characterization of PABA was performed before formulation to confirm identity, purity, and suitability as a UVB filter. The UV–visible spectrophotometric analysis showed a λmax of 288 nm in ethanolic phosphate buffer (pH 7.4), consistent with reported values [18–20]. The melting point ranged from 187–189°C, indicative of high purity and absence of major impurities. PABA exhibited the highest solubility in ethanol, moderate solubility in propylene glycol, and poor solubility in water, supporting its incorporation in the oil phase with the aid of a suitable cosolvent. The partition coefficient (log P) value of 5.135 suggests lipophilicity, which favors its retention on the skin surface, thereby enhancing topical efficacy.

A calibration curve constructed for PABA in the concentration range of 1–10 μg/ml showed a high degree of linearity ($R^2 > 0.998$), enabling accurate quantification of drug content in the formulations.

### Sensory (Psychometric) Evaluation

The acceptability of a topical cream is heavily influenced by its sensory attributes, which directly affect patient compliance. All six formulations (C1–C6) were evaluated for appearance, ease of spread, after-feel, and residue. The creams exhibited a uniform white to off-white appearance, smooth texture, and absence of grittiness. Formulations containing aloe vera (C4–C6) scored higher in spreadability and after-feel due to the moisturizing and lubricating effect of aloe mucilage. A minimal greasy residue was reported in higher PABA content formulations (C3 and C6), possibly due to increased oil phase proportion needed to dissolve PABA.

The hedonic scale ratings indicated that C5 achieved the optimal balance, with “good” to “very good” scores in all categories. This is significant because consumer preference strongly determines the success of sunscreen formulations in the market, particularly in hot, humid climates, like India, where greasy products are poorly tolerated.

### Physicochemical Properties (Table 2)

- *pH:* Values ranged between 5.91 and 6.17, within the skin-compatible range (4.5–6.5), minimizing the risk of irritation.
- *Dye Test:* All formulations were confirmed as oil-in-water (O/W) emulsions, desirable for sunscreen creams due to their lighter feel and ease of removal.
- *Acid and Saponification Values:* Acid values (6.01–6.61) were within pharmacopeial limits, indicating minimal hydrolytic degradation of oils. Saponification values confirmed the consistency of the oil phase composition.
- *Extrudability:* Values ranged from 3.8 to 5.2 seconds for a 1 cm ribbon, suggesting adequate tube dispensing properties without excessive stiffness or fluidity.
- *Spreadability:* Higher aloe vera content correlated with faster spread (due to increased aqueous phase content), enhancing application comfort.
- *Viscosity:* Brookfield viscosity measurements indicated pseudoplastic flow behavior typical of emulsions. C5 exhibited intermediate viscosity (~19,800 cps), which provided good stability without impairing spreadability.
- *Drug Content:* Recovery ranged from 74.5% (C1) to 90.7% (C6). Lower PABA concentrations showed slightly reduced percentage recovery, likely due to analytical sensitivity limits at low concentrations.

### In-vitro SPF Evaluation

In-vitro SPF determination revealed values ranging from 2.96 (C1) to 7.45 (C6). A proportional increase in SPF was observed with increasing PABA concentration, confirming its dose-dependent photoprotective activity. Notably, formulations containing aloe vera (C4–C6) consistently showed higher SPF values compared with their aloe-free counterparts (C1–C3) at the same PABA concentration. This enhancement could be attributed to aloe vera's antioxidant activity and possible light-scattering effects due to its polysaccharide matrix (Tables 3 and 4) [21–24].

**Table 2.** Solubility profile of PABA.

| S.N. | Solvent | Solubility (mg/ml) |
|---|---|---|
| 1 | Water | 0.132 |
| 2 | Alcohol | 5.02 |
| 3 | Propylene glycol | 4.565 |
| 4 | Phosphate buffer pH 7.4 | 2.69 |

The calibration curve of PABA was prepared in ethanolic phosphate buffer pH 7.4 at 288 nm λ max, and the values of different concentrations of PABA solution in ethanolic phosphate buffer pH 7.4 are presented in Table 5 and graphically represented in Figure 1. Beer's law was found to obey in the range of 1–10 µg/ml (Figure 1).

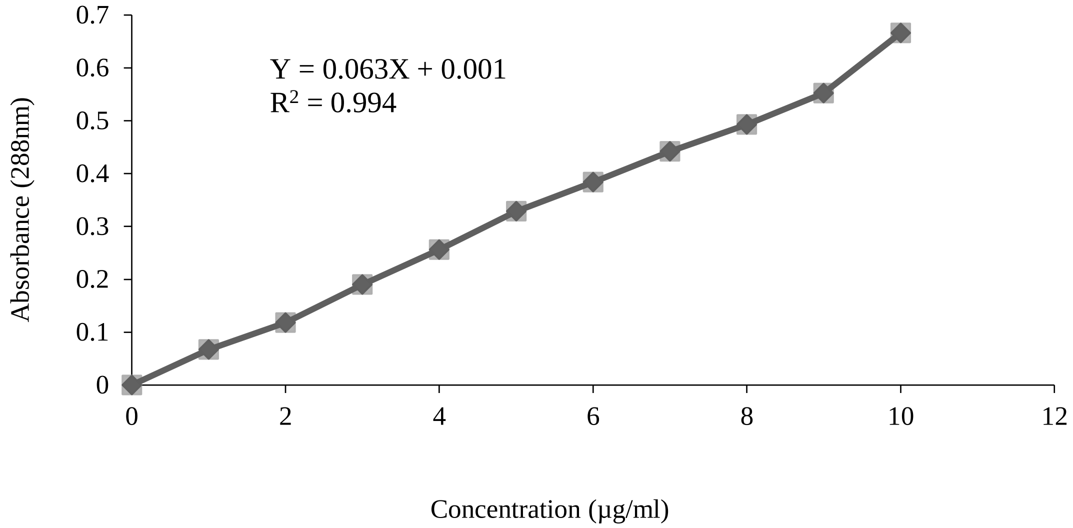



**Figure 1.** Calibration curve of PABA.

**Viscosity Study**

A Viscosity Study was carried out for all these formulations using a brookfield viscometer using spindle S-95 (Figures 2–7).

*In-vitro* SPF Determination: Photo-protective formulations were assigned from C1 to C6. SPF determination table for photo-protective formulations (Table 5).

***In vivo* SPF Determination**

Based on evaluation parameters, the formulation (C5), which shows satisfactory results, and selected for *in vivo* SPF determination. The study was done on a panel of 18 human volunteers; they were divided into 6 groups (each containing 3) (Tables 6 and 7).

**Stability Studies**

All formulations remained physically stable after five freeze–thaw cycles between 25°C and−5°C, with no signs of phase separation, color change, or rancidity. Viscosity values showed negligible deviation (<3% change), and pH remained within ±0.1 units of initial readings. These results indicate that the emulsifying system and preservatives used were effective in maintaining stability under thermal stress conditions [25, 26].

**Table 3.** Psychometric evaluation.

| Parameter | C1 | C2 | C3 | C4 | C5 | C6 |
|---|---|---|---|---|---|---|
| *Appearance* | Off white | Off white | Off white | Off white | Off white | Off white |
| Color intensity | Hue | Hue | Hue | Hue | Hue | Hue |
| Gloss | Opacity | Opacity | Opacity | Opacity | Opacity | Opacity |
| Roughness | Smooth | Smooth | Smooth | Smooth | Smooth | Smooth |
| *Rub out* | | | | | | |
| Oilyness | + | + | + | + | + | + |
| Spreadability | + | + | + | + | + | + |
| Thickness | + | + | + | + | + | + |
| Absorbency | + | + | + | + | + | + |
| *After feel* | | | | | | |
| Stickness | – | – | – | – | – | – |
| Slipperiness | + | + | + | + | + | + |
| Amount of residue, type of residue | – | – | – | – | – | – |
| *Pickup* | | | | | | |
| Firmness | + | + | + | + | + | + |
| Stickiness | – | – | – | – | – | – |
| Cohesiveness | + | + | + | + | + | + |
| *Peaking* | + | + | + | + | + | + |

**Table 4.** Physicochemical evaluation.

| Formulation Code | pH | Type of Emulsion | Acid Value | Saponification Value | Excrudibility (Second) | Spreading (gm cm/sec) | Drug Content (%) |
|---|---|---|---|---|---|---|---|
| C1 | 5.91 | O/W | 6.31 | 22.9 | 6.5 | 28.9 | 74.5 |
| C2 | 5.97 | O/W | 6.01 | 19.6 | 6.8 | 24.8 | 87.2 |
| C3 | 6.17 | O/W | 6.23 | 19.3 | 7.2 | 24.3 | 90.7 |
| C4 | 6.12 | O/W | 6.50 | 21.8 | 6.8 | 24.4 | 79.9 |
| C5 | 6.10 | O/W | 6.61 | 20.7 | 6.9 | 24.6 | 84.2 |
| C6 | 6.07 | O/W | 6.30 | 19.8 | 7.5 | 23.8 | 89.2 |

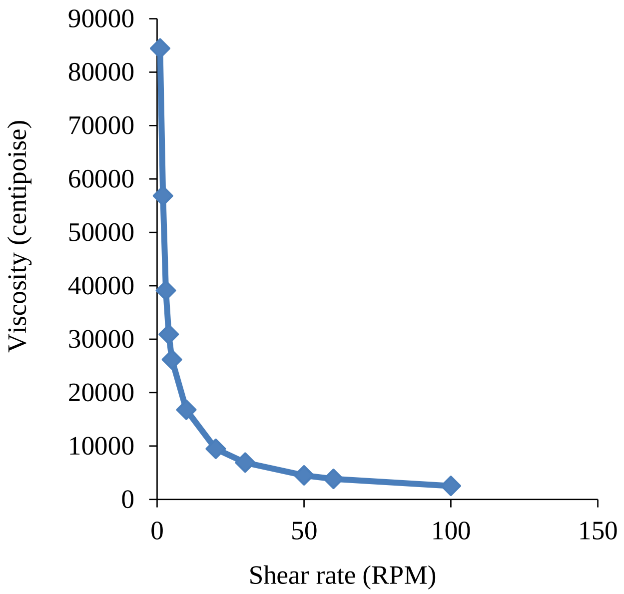



**Figure 2.** Graph between Viscosity and Shear Rate viscosity for formulation C1.

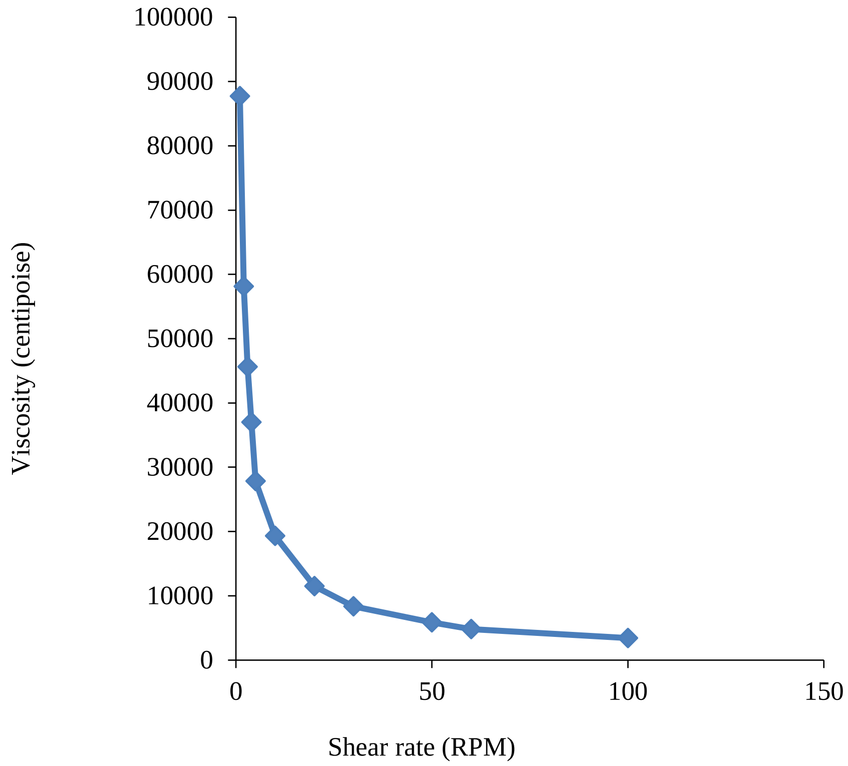



**Figure 3.** Graph between Viscosity and Shear Rate viscosity for formulation C2.

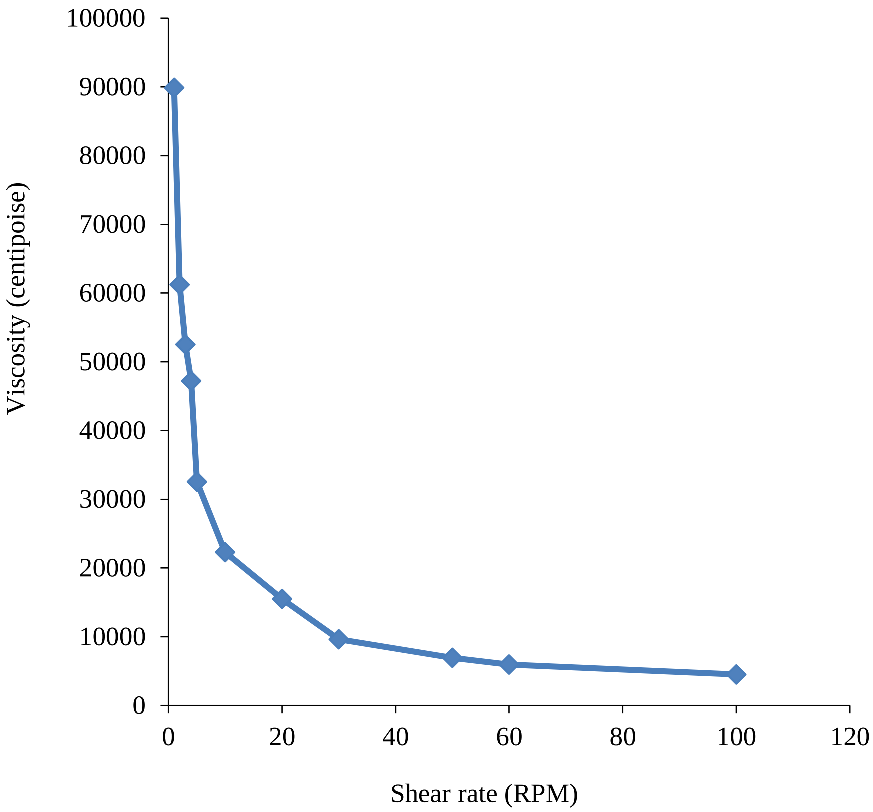



**Figure 4.** Graph between Viscosity and Shear Rate viscosity for formulation C3.

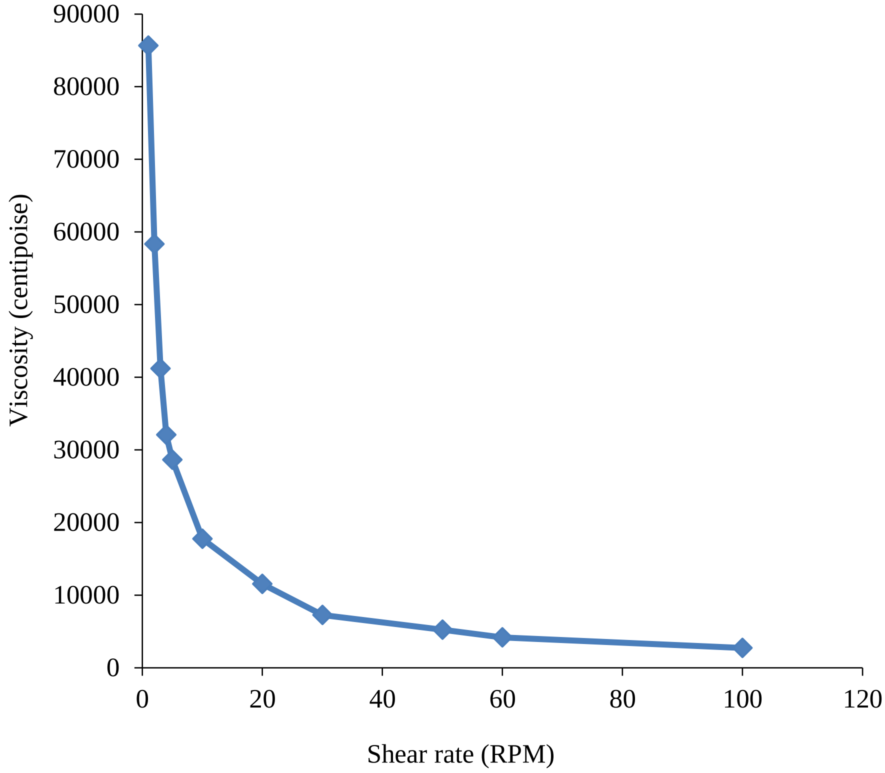



**Figure 5.** Graph between Viscosity and Shear Rate viscosity for formulation C4.

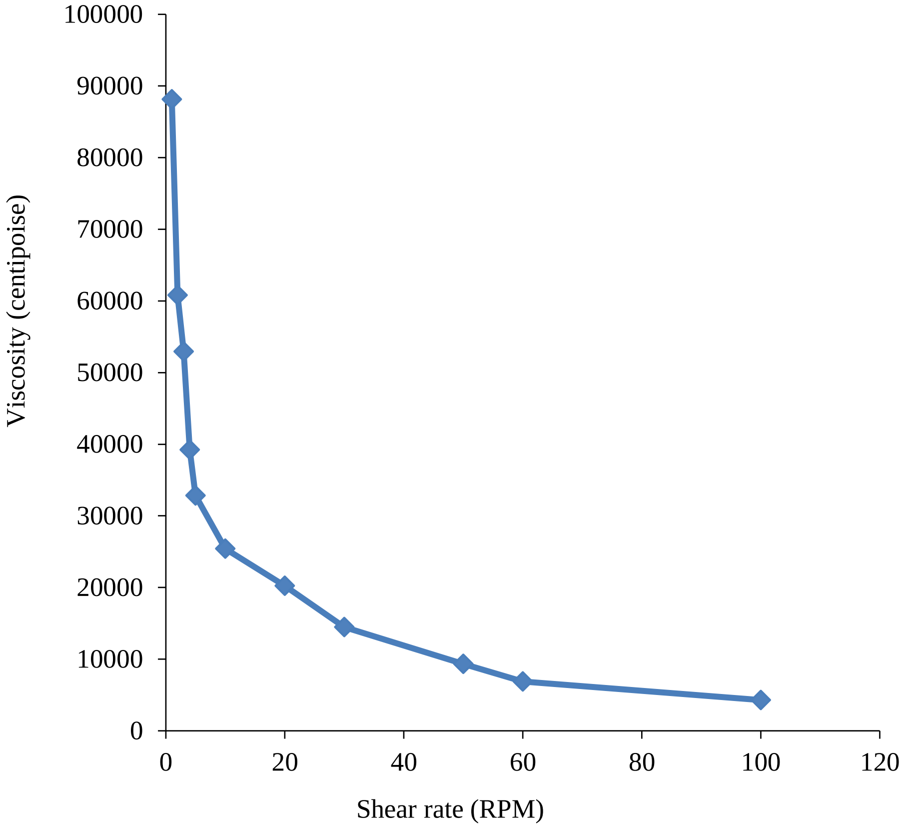
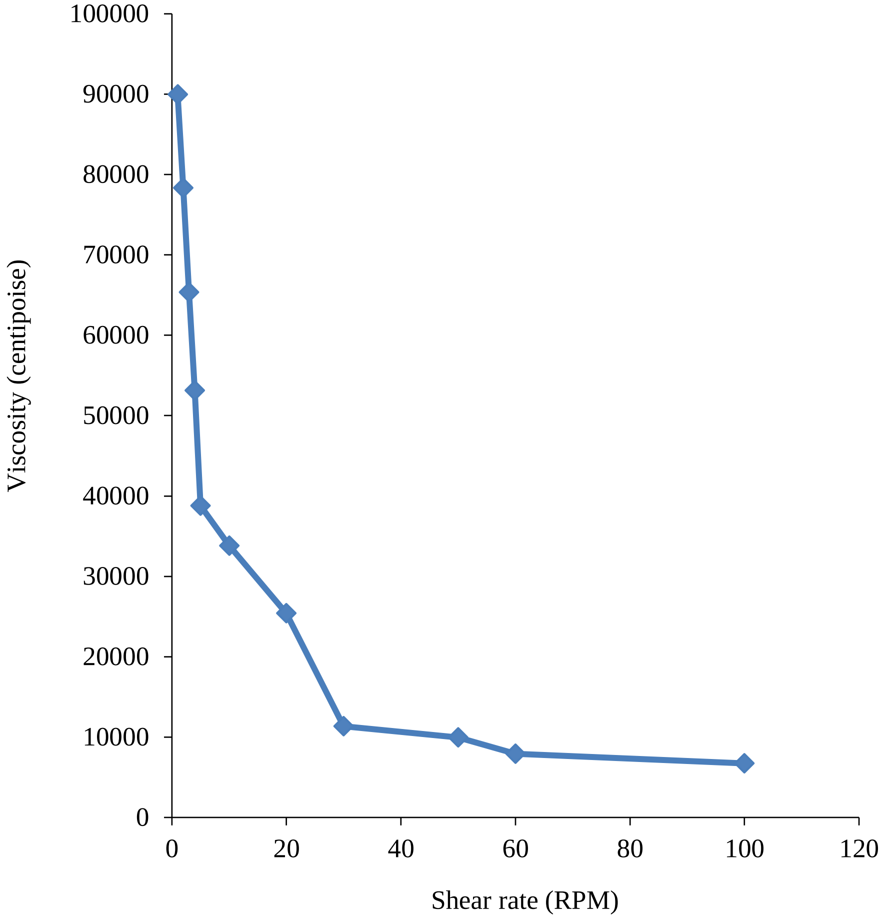



**Figure 6.** Graph between Viscosity and Shear Rate viscosity for formulation C5.




**Figures 7.** Graph between Viscosity and Shear Rate viscosity for formulation C6.

**Table 5.** *In-vitro* SPF determination.

| S.N. | λ (nm) | EE(λ)X I(λ) | Absorbance | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | ***C1*** | ***C2*** | ***C3*** | ***C4*** | ***C5*** | ***C6*** |
| 1 | 290 | 0.0150 | 0.501 | 0.639 | 0.889 | 0.621 | 0.889 | 0.982 |
| 2 | 295 | 0.0187 | 0.493 | 0.629 | 0.803 | 0.523 | 0.812 | 0.901 |
| 3 | 300 | 0.2874 | 0.434 | 0.423 | 0.732 | 0.503 | 0.560 | 0.889 |
| 4 | 305 | 0.3278 | 0.320 | 0.406 | 0.693 | 0.454 | 0.502 | 0.824 |
| 5 | 310 | 0.1864 | 0.200 | 0.366 | 0.534 | 0.394 | 0.417 | 0.650 |
| 6 | 315 | 0.0839 | 0.095 | 0.109 | 0.403 | 0.174 | 0.269 | 0.546 |
| 7 | 320 | 0.180 | 0.027 | 0.093 | 0.109 | 0.100 | 0.109 | 0.115 |
| SPF | | | 2.964 | 3.66 | 6.383 | 4.184 | 6.770 | 7.447 |

**Table 6.** *In-vivo* SPF determination.

| Groups (N = 3) | Erythemal Time (Min) (Unprotected) | Erythemal Time (Min) (Unprotected) | SPF (N = 3) |
|---|---|---|---|
| | | ***C5*** | ***C5*** |
| 1 | 18 | 127 | 7.05 ± 0.33 |
| 2 | 25 | 132 | 5.28 ± 0.13 |
| 3 | 26 | 147 | 5.65 ± 0.18 |
| 4 | 19 | 130 | 6.84 ± 0.23 |
| 5 | 22 | 148 | 6.72 ± 0.59 |
| 6 | 20 | 134 | 6.70 ± 0.03 |

**Table 7.** Comparative study table for in vitro and in vivo SPF of formulation C5.

| S.N. | Formulation Code | In Vitro SPF | In Vivo SPF |
|---|---|---|---|
| 1 | C5 | 6.7 | 6.2 |

## Comparative Literature Discussion

Several studies have explored the use of PABA and herbal extracts for sunscreen development. For example, a study by Mansur et al. (1986), Seifert (1987), and Garcia et al. (1990) [15, 27–29] reported SPF values in the range of 5–8 for creams containing 3% PABA. In the present work, SPF values of 6.2–7.45 were achieved with only 2%–3% PABA when combined with aloe vera, suggesting potential synergistic benefits. Furthermore, while commercial broad-spectrum sunscreens often rely on combinations of chemical and physical filters, the present study demonstrates that cost-effective protection can be achieved using a single chemical absorber in optimized concentration, supplemented with a natural agent like aloe vera.

From a formulation perspective, the choice of an O/W emulsion base contributes to consumer acceptability in tropical climates, where heavy oil-based creams may cause discomfort. Additionally, the use of sesame oil and almond oil not only serves as a solvent for PABA but also contributes to skin nourishment and barrier repair [30–33].

## Practical Implications

The affordability of this formulation is a critical factor in its public health relevance. Imported branded sunscreens in India often retail at 300–800 INR for 50 ml, placing them out of reach for low-income populations. The present formulation uses inexpensive, locally sourced raw materials, potentially reducing production costs to under 60–80 INR for the same volume. This opens possibilities for government-led or NGO-supported mass distribution programs, especially for outdoor workers and rural communities.

## CONCLUSIONS

This study successfully developed and evaluated cost-effective UVB-protective creams using PABA as the active sunscreening agent, with and without aloe vera. The systematic evaluation demonstrated that:

1. Formulation C5 (2% PABA + 10% aloe vera) achieved the best balance between SPF efficacy, sensory attributes, and stability.
2. Increasing PABA concentration proportionally improved SPF values, and aloe vera addition provided an additional enhancement, likely due to antioxidant and moisturizing effects.
3. All formulations maintained physicochemical stability under freeze–thaw conditions, supporting their suitability for storage and distribution in variable climates.
4. The combination of low-cost raw materials and simple manufacturing processes positions this formulation as a viable option for large-scale production aimed at high-UV regions such as India.

Future work should focus on:

- Expanding SPF testing to include UVA protection measurements for broader spectrum coverage.
- Conducting long-term photostability studies under simulated solar radiation.
- Investigating molecular-level skin protection mechanisms through histological and biochemical analyses.
- Performing consumer field trials to assess long-term acceptability and compliance in diverse climatic conditions.

By bridging the gap between affordability and efficacy, this research provides a foundation for community-level photoprotection strategies in developing nations.

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