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Development & Evaluation Of Natural-Based Broad-Spectrum Photoprotection Sunscreen Effective Against UVA And UVB Radiation

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Abstract

Exposure to ultraviolet (UV) radiation is a major cause of skin damage, including erythema, photoaging, oxidative stress, hyperpigmentation, and skin cancer. Therefore, the development of effective broad-spectrum sunscreen formulations capable of protecting against both UVA and UVB radiation is essential. The present study aimed to develop and evaluate a natural-based broad-spectrum sunscreen cream containing zinc oxide and titanium dioxide as mineral UV filters. Three formulations were prepared using the hot emulsification method and evaluated for their physicochemical properties, stability, and photoprotective efficacy. The optimized formulation was assessed for appearance, pH, viscosity, texture, spreadability, phase separation, particle size distribution, Sun Protection Factor (SPF), and accelerated stability. The developed sunscreen cream exhibited a smooth, homogeneous texture with good spreadability and acceptable cosmetic characteristics. The formulation showed a skin-compatible pH of 7.00 and a viscosity of 40,000 cps, indicating suitable rheological behavior for topical application. Texture analysis demonstrated desirable hardness, cohesiveness, and adhesiveness properties, contributing to ease of application and consumer acceptability. The spreadability value was found to be 8.3 g·cm/sec, indicating uniform skin coverage. No phase separation was observed during centrifugation studies, confirming good emulsion stability. Particle size analysis revealed a Z-average particle size of 976 nm with a polydispersity index of 0.312, indicating acceptable homogeneity of the formulation. The sunscreen cream exhibited a high SPF value of 57.34, demonstrating excellent photoprotective efficacy against ultraviolet radiation. Furthermore, accelerated stability studies showed no significant changes in appearance, pH, viscosity, or phase separation under different storage conditions. The findings suggest that the developed natural-based sunscreen cream possesses excellent stability, desirable physicochemical characteristics, and effective broad-spectrum photoprotection, making it a promising candidate for safe and efficient skin protection against UVA and UVB radiation.

Keywords: Broad-spectrum sunscreen, Zinc oxide, Titanium dioxide, Sun Protection Factor, Photoprotection, UVA, UVB, Stability study.

Introduction

The skin is the largest organ of the human body and serves as the primary protective barrier against environmental stressors, including solar ultraviolet (UV) radiation. Although melanin produced by melanocytes provides a natural defense against UV exposure, prolonged and excessive exposure to ultraviolet radiation can overwhelm this protective mechanism and result in various skin disorders. UV-induced skin damage includes erythema, hyperpigmentation, photoaging, oxidative stress, immunosuppression, DNA damage, and skin carcinogenesis. Consequently, effective photoprotection has become an essential aspect of dermatological care, preventive healthcare, and cosmetic science [1,2].

Solar ultraviolet radiation is classified into three regions: UVC (100–290 nm), UVB (290–320 nm), and UVA (320–400 nm). UVC radiation is largely absorbed by atmospheric ozone and does not reach the Earth's surface, whereas approximately 95% of the UV radiation reaching the skin consists of UVA and only 5% comprises UVB radiation. Despite its lower proportion, UVB possesses higher energy and primarily affects the epidermis, causing sunburn, inflammation, direct DNA damage, and initiation of skin cancer. In contrast, UVA penetrates deeply into the dermis, generating reactive oxygen species (ROS), accelerating collagen and elastin degradation, inducing pigmentation, and contributing significantly to premature skin aging and photoaging [3–5].

The harmful effects of UV radiation are primarily mediated through the generation of reactive oxygen species, which interact with cellular proteins, lipids, and nucleic acids, resulting in oxidative stress and structural damage. Continuous exposure to solar radiation not only accelerates skin aging but also increases the risk of photocarcinogenesis. Therefore, minimizing UV-induced skin damage through the use of effective sunscreen products is crucial for maintaining skin health and preventing long-term dermatological complications [2,5].

Sunscreens are topical photoprotective formulations designed to absorb, reflect, scatter, or block ultraviolet radiation before it penetrates the skin. Conventional sunscreen products generally contain synthetic organic UV filters such as oxybenzone, octinoxate, octocrylene, and avobenzone, as well as inorganic mineral filters including zinc oxide and titanium dioxide. These ingredients provide protection against UVA and UVB radiation and significantly reduce the risk of UV-induced skin damage [6,7].

Among the available UV filters, zinc oxide and titanium dioxide are widely recognized as effective broad-spectrum photoprotective agents. These mineral filters act by reflecting, scattering, and partially absorbing UV radiation across both the UVA and UVB regions. They exhibit excellent photostability and provide immediate protection upon application. However, their use is often associated with cosmetic limitations such as whitening effects, poor aesthetic appearance, and formulation challenges. Moreover, increasing concerns regarding the safety of certain synthetic UV filters, including skin irritation, allergic reactions, systemic absorption, endocrine-disrupting potential, and environmental toxicity, have encouraged the search for safer and more sustainable alternatives [7–9].

In recent years, natural products have gained considerable attention as promising alternatives for sunscreen development. Plant-derived bioactive compounds such as flavonoids, polyphenols, tannins, anthocyanins, carotenoids, and phenolic acids possess intrinsic UV-absorbing properties and strong antioxidant activity. These phytochemicals can effectively neutralize reactive oxygen species generated during UV exposure and protect cellular components from oxidative damage. In addition to their photoprotective potential, many natural compounds exhibit anti-inflammatory, antimicrobial, wound-healing, and skin-soothing properties, making them attractive multifunctional ingredients for sunscreen formulations [10,11].

Several medicinal plants and botanical extracts, including green tea (*Camellia sinensis*), aloe vera (*Aloe barbadensis*), turmeric (*Curcuma longa*), pomegranate (*Punica granatum*), grape seed (*Vitis vinifera*), and hibiscus (*Hibiscus rosa-sinensis*), have demonstrated significant UV-protective and antioxidant activities. The presence of aromatic rings and conjugated double-bond systems within these phytochemicals enables absorption of both UVA and UVB radiation, thereby contributing to broad-spectrum photoprotection. Furthermore, the antioxidant properties of these natural ingredients help

prevent collagen degradation, lipid peroxidation, and oxidative DNA damage associated with chronic UV exposure [10–12].

Broad-spectrum sunscreens capable of protecting against both UVA and UVB radiation are essential because protection against UVB-induced sunburn alone does not eliminate the long-term risks associated with UVA exposure. Regulatory authorities and dermatological organizations therefore recommend the use of broad-spectrum sunscreen products as part of comprehensive photoprotection strategies. An ideal sunscreen formulation should not only provide effective UV protection but also possess acceptable physicochemical stability, spreadability, skin compatibility, photostability, and consumer acceptability [6,8].

The incorporation of natural bioactive compounds into sunscreen formulations offers the opportunity to develop multifunctional products that combine photoprotection with antioxidant and skin-beneficial effects while minimizing the potential risks associated with synthetic UV filters. Therefore, the development of natural-based broad-spectrum sunscreen systems represents a promising approach toward safer, eco-friendly, and sustainable photoprotective products.

In view of these considerations, the present study focuses on the development and evaluation of a natural-based broad-spectrum sunscreen formulation effective against both UVA and UVB radiation. The developed formulation was evaluated for its physicochemical characteristics, stability, antioxidant potential, and photoprotective efficacy to determine its suitability as a safe and effective sunscreen product for enhanced skin protection.

Material and Methods

Active Profile:

INCI NAME: Zinc Oxide (and) Coco-Caprylate/Caprate

Common Name: Zinc blend.

Introduction

Zinc blend is a 65 wt% dispersion of uncoated zinc oxide in coco-caprylate /caprate, for use in a variety of suncare, skincare and cosmetics applications.

Zinc blend provides zinc oxide (ZnO) particles offering broad spectrum UV protection with exceptional transparency, allowing the formulation of elegant skincare products that do not cause unacceptable whiteness on the skin.

Physical Parameter

Parameter	Result
State	Liquid dispersion
Appearance	off white to light yellow
Odor	Mild odor
Solubility	Insoluble in Water
Particle size	Greater than 1.00 um
Flash point	>150°C
Specific gravity	1.9

Table no. 1 Physical Parameter of Zinc Oxide

Chemical Composition.

INCI NAME	CAS No
Zinc Oxide	1314-13-2
Coco-caprylate/caprate	95912-86-0

Table no. 2 Chemical composition Zinc

Broad Spectrum Protection

Zinc blend has a broad absorption profile spanning both UVA and UVB. Zinc blend may be used alone or in combination with other UV filters to produce high SPF sunscreens that will meet the UVAPF>1/3SPF criterion where required. Zinc blend can also be formulated for the critical wavelength

to reach 370nm where required. Zinc blend is photostable in formulations and is not prone to degrade or lose effectiveness under influence of UV.

Typical Performance / Required Loadings

Zinc blend can be formulated at high loadings to achieve high SPF without compromising the clarity of the end product. The table below serves as a guide only, as the SPF will additionally depend on the type of formulation.

SPF Target	Zinc Blend Loading	Zinc Loading
15-20%	20-30%	13-19.5%
20-40%	30-35%	19.5-23%
40%	35-38%	23-25%

Table no. 3 Zinc loading

Zinc blend Particle Morphology:

The zinc oxide particles in Zinc blend consist of primary particles, which form aggregates up to a few tens of micrometres in size. Larger aggregates have a unique porous structure that provides a closer match between the refractive index of the particle and the refractive index of the emollient, resulting in high transparency.

Typical Application

- Natural sunscreens, cosmetics and skincare
- Mineral only sunscreens
- Low irritant or sensitive skin sunscreens
- Baby and children's sun care products
- Nappy rash creams and balms
- Daily wear skincare and cosmetics delivering sun protection
- Lip balms
- Colour cosmetics

Natural Certification :Zinc blend is currently certified as compliant with the Natural Product Association (USA) & COSMOS (EU).

Active Profile:

INCI NAME: Titanium Dioxide (and) Caprylic/Capric Triglyceride.

Common Name: Titanium blend.

Introduction

Fine and stable dispersion of UV grade and broad spectrum titanium dioxide in cosmetic oils at high % of active. It can be incorporated easily with the conventional equipments into any personal care products to provide the broad-spectrum sun protection benefit.

Physical Parameter

Parameter	Result
State	Liquid Dispersion
Color	Off white soft cream
Odor	Mild
Solubility	Insoluble in Water

Table no. 4 Physical Parameter of Titanium dioxide

Chemical Composition

INCI NAME	CAS No
Titanium dioxide	13463-67-7
Coco-caprylate/caprate	95912-86-0

Table no. 5 Chemical composition Titanium dioxide

Broad Spectrum Protection

Meet with global UVA criteria: FDA of USA: critical wavelength > 370 nm; PA +++ of Asia; UVAPF/SPF > 1/3 of EU

Typical Performance / Required Loadings

G-Block DTB 300 CCT is formulated to provide broad spectrum protection with maximum % of Titanium loading to boost the SPF without compromising the quality of finish product.

SPF Target	TiO2 Blend	TiO2 Loading
3 SPF	1%	0.6%

Table no. 6 Titanium dioxide loading

Safety data:

Repeated Insult Patch Test (RIPT) with 50 human subjects shows no skin irritation and no skin sensitization. The titanium dioxide powder before the coating of a thin alumina layer (for further protection of skin against radicals) and dispersion meets with USP standard. The powder is designed and manufactured for strong broad Spectrum UV protection.

Total heavy metal < 20 ppm, and Arsenic < 2 ppm

Microbiology data: Total aerobic bacteria count and the total yeast/mold count < 100 cfu/g, free of Pathogens: E.Coli, P. Aeruginosa, and S. Aureus.

Typical Application

- Natural sunscreens that meet with all global regulations for broad spectrum and "natural" standards.
- Sunscreens for baby and people with sensitive skin.
- Sport sunscreens with long lasting UV A and B protection.
- Daily skin care lotion and cream with UV A and B protection.
- Natural Color cosmetics with sunscreen benefit

Natural Certification

ECOCERT and Natural Product Association (NPA) approved for natural sunscreens which meet with global regulations.

Preparation of Sunscreen Cream:

1. For preparation of Sunscreen Cream 1st Weigh all the Oil phase solid ingredients in clean & dry beaker, after that weigh oils in same beaker.
2. In 2nd beaker weigh Aqueous Phase ingredients.
3. Cover both phases with foil paper & placed in hot water bath.
4. Wait until the temperature of both phase is 75-80° C.
5. Then deep the stirring rod into aqueous phase & poured oil phase into aqueous phase & Stirred at 3000 to 5000 RPM (with IKA T25 Ultra Turrax high speed homogenizer)
6. After stirring Preservative was added at 40° C & Stirred.
7. Maintained the pH up to 7.00.
8. Filled the prepared product in well labelled Container.

6.4 Formulation Table:

Phases	Ingredients	For 100%		
		F-1	**F-2**	**F-3**
A	DM water	Upto 100 %	Upto 100%	**Upto 100%**
	Glycerine	3	4	**3.5**
	Gum TX	2	2.2	**1.5**
	Sodium Phytate	0.1	0.2	**0.3**
B	ML	0.5	1.5	**1**
	Alkyl Glycoside and Alcohol	4	5	**6**
	Coco caprylate / caprate	3	2.5	**4**
	Oil B	3	1.6	**5**
	Oil AM	1	1.5	**2**
	Oil A	3	2.5	**1.7**
	Olive oil	0.3	o.6	**0.8**
	Oil GP	5	5	**6**
	Oil R	0.5	0.6	**0.7**
	Titanium Oxide Blend	5	5	**5**
	Zinc Oxide Blend	20	20	**20**
	Squlane	2	3	**1**
C	Cellulose	4	3	**2.5**
	Sodium Levulinate; Potassium Sorbate	0.5	1.5	**2**
	Total	100	100	**100**

Table no. 7 Formulation Table

Evaluation of Formulation:

1. **Physical Evaluation:**

This includes a visual inspection to assess the formulation's appearance, color, and odor these characteristics is essential to ensure not only the aesthetic appeal but also the overall quality of the formulation. Homogeneity and texture were tested by pressing a small quantity of the formulated cream and gels between the thumb and index finger. The consistency of the formulations and presence of coarse particles were used to evaluate the texture and homogeneity of the formulations.

2. **Determination of pH:**

- Accurately weighed quantities of the Sunscreen cream were dissolved with a known quantity of deionized water to make a 10% w/v dispersion system.
- The pH of this 10% w/v dispersion of Sunscreen cream was determined using a digital pH meter.
- A pH measurement of the sample was performed in triplicate, and the average value was reported.

3. **Determination of Viscosity:**

- The viscosity of sunscreen cream was determine by Brookfield viscometer **(Model No – D 220).**
- Test sample was taken in a clean and dry 100 ml beaker.
- The viscosity was measure using spindle nos. 1–7.
- The spindle was used according to formulation for finding the viscosity of the sample at speeds of 0.3, 0.6, 1.5, 3, 6, 12, 30 and 60 RPM, respectively.
- Their rheological characteristics were also tested at 25^{o}C using Brookfield viscometer.

4. Determination of Texture Analysis:

The sample were carefully Filled into the sample cup, ensuring the complete absence of air entrapment. The analysis was carried out using the instrument CT3 Texture Analyzer (Brookfield Engineering labs, Inc., USA). (Software-TexturePro CT V1.3)

The experimental conditions were set as follows: 10000 g load cell, 0.5 mm/s test speed, 6.00 mm target value and 7g trigger load. For the analysis, the texture profile analysis (TPA) was selected and the cone probe TA3/100 was used. The parameters measured included, Hardness cycle 1, Hardness work, Adhesiveness & Cohesiveness.

5. Procedure for Texture Analysis:

1. Materials and Equipment:

Sample: e.g., Sunscreen Cream

Texture Analyzer instrument

Appropriate probe: Typically cylindrical (e.g., 5 mm or 10 mm diameter) or conical probe

Sample holder (e.g., beaker or cup)

Computer with texture analysis software (e.g., TexturePro CT V1.3)

2. Sample Preparation:

Ensure uniformity of the sample.

Fill the sample holder uniformly (without air bubbles).

Level the surface to maintain consistent testing depth.

3. Instrument Setup:

Set up the Texture Analyzer with the following typical test settings (these may vary based on product type):

- Test mode: Compression or penetration test
- Probe type: Cylindrical or cone (e.g., P/5, P/10)
- Pre-test speed: 1.0 mm/s
- Test speed: 0.5–2.0 mm/s
- Post-test speed: 1.0 mm/s
- Target mode: Distance (e.g., 6 mm penetration)
- Trigger force: 7 g (force at which the test begins)
- Data acquisition rate: 20 points/sec (or as appropriate)

4. Performing the Test:

Place the filled sample holder under the probe.

Start the test using the software.

The probe moves downward to compress or penetrate the sample and then retracts.

Force–time or force–distance graph is generated.

5. Data Analysis:

Software computes texture parameters from the force–distance curve:

Peak force: Hardness

Area under the curve (compression): Work done (firmness or consistency)

Negative force area (probe withdrawal): Adhesiveness.

7. Determination of spreadability:

Spreadability is expressed in terms of time in seconds taken by two slides to slip off from the cream when placed in between the slides under the direction of a certain load. The excess amount of sample was placed between the two glass slides and a definite amount of weight was placed on these glass slides to compress the glass slides of uniform thickness.

A weight of 70 g was added and the time required to separate the two slides was noted. Spreadability was calculated using the formula.

$S = M.L/T$

Where,

M = Weight tied to the upper slide (g), L = length of glass slides(cm), T = time taken to separate the slides(sec).

Values,

8. Procedure for Testing Spreadability

Method:

Slide to Slip off.

Materials Required:

- Two glass slides (5 × 5 cm)
- Wooden block with a pulley
- Weights
- Stopwatch
- Cosmetic sample (cream/gel/lotion)

Procedure:

1. Weigh a specific amount (e.g., 2 g) of the cosmetic formulation and place it between two glass slides.
2. Place a 1 kg weight on top of the slides for 5 minutes to allow the sample to spread and remove air bubbles.
3. Tie the upper slide with a string that passes over a pulley.
4. Attach a standard weight (e.g., 70 g) to the string to pull the upper slide horizontally.

Measure the time (in seconds) taken by the upper slide to move a fixed distance (e.g., 5 cm).

Calculate Spreadability (S) using the formula: $S=TM\times L$

Where:

S = Spreadability (g·cm/sec)

M = Weight tied to the upper slide (g)

L= Length the slide moves (cm)

T = Time taken (sec) [39]

9. Determination of phase separation (Centrifugation):

This experiment was conducted using an automated centrifuge after 9 days of product formulation at an rpm of 3000 for 18 min to assess the physical stability of the formulations. The study was repeated after 15 and 30 days. All measurements were conducted at room temperature.

10. Procedure for Centrifugation:

Materials Needed:

- Sunscreen sample
- Centrifuge (high-speed tabletop or refrigerated)
- Centrifuge tubes (15 mL or 50 mL, depending on sample size)
- Balance tube for counterweight
- Lab balance
- Refrigerator (optional for cold centrifugation)

11. Procedure for centrifugation:

1. Sample Preparation:

Pour a fixed volume of the Sunscreen cream (e.g., 5–10 gm) into a clean centrifuge tube.

Ensure the emulsion is homogeneous before testing (gently mix, do not vortex).

2. Balancing the Tubes:

Weigh the centrifuge tube and adjust with distilled water or blank emulsion in a second tube to match the weight exactly (±0.01 g).

Place the tubes opposite each other in the rotor to balance.

3. Centrifuge Settings:

Speed: 3000 to 15000 rpm (Commonly used: 5000–10,000 rpm)

Time: 15 to 30 minutes

Temperature: Room temperature (25 °C) or 4 °C (if testing cold stability).

4. Centrifugation Process:

Close the centrifuge lid securely.

Start the centrifuge with selected speed and time.

Do not disturb or open until it stops completely.

5. Post-Centrifugation Observation:

- Examine the samples visually for:
- Phase separation (oil layer on top or water layer at bottom)
- Creaming (lighter phase rising to the top)
- Sedimentation (droplets settling)
- Coalescence or cracking (droplets merging irreversibly)
- If possible, perform droplet size analysis (DLS) before and after centrifugation to detect subtle instability.

12. 1Determination of SPF:

The assessment of SPF *in vitro* can be done using determining absorption characteristics of sunscreen cream based on spectrophotometric analysis of dilute solutions. By UV spectrophotometric technique and employing a simple formula developed by Mansur equation.

The *in vitro* SPF can be calculated by following equation:

$$SPF = CF \times \sum_{290}^{320} EE(\lambda).I(\lambda).Abs(\lambda)$$

Where,

EE: erythemal effect spectrum;

I: solar intensity spectrum;

Abs: absorbance of sunscreen product;

CF: correction factor (= 10)

Wavelength λ (nm)	**EE×I**
290	0.015
295	0.0817
300	0.2874
305	0.3278
310	0.1864
315	0.0839
320	0.018
Total	1

Table no 8 Normalized product function used in the calculation of SPF

Procedure for SPF:

Method: UV-VIS Spectroscopy.

Materials Required:

- Weighing Balance.
- Apparatus (Beakar, volumetric flask,Test tube,etc)
- Solvent (Ethanol, Methanol or Water)
- Sunscreen Sample.

Sample Preparation:

1. The cream was diluted to 20 ppm.
2. From each cream formula, a 1-gram sample was taken and dissolved in 100 mL of ethanol.
3. Sonication for 5 min.
4. Then 10 mL of the sample solution was taken and dissolved in 100 mL of ethanol.
5. 10 mL of aliquot solution was dissolved in 50 mL of ethanol.
6. 5 mL of aliquot solution was dissolved in 50 mL of ethanol.

Instrument Setup:

Use a double-beam UV-Vis spectrophotometer (e.g., UV-Spectrophotometer).

Set the wavelength range from 200 to 400 nm

Blank Calibration:

Calibrate the instrument using ethanol as the blank.

Measurement:

Measure the absorbance of a sample solution at 290-320 nm.

Plot Calibration Curve:

Plot absorbance (Y-axis) vs. wavelength (X-axis).

Perform linear regression to find slope (m) and intercept (b).

Ensure $r^2 > 0.99$ for acceptable linearity.

Calculation:

Then calculate the SPF value using the Mansur equation. [52]

13. Determination of Particle Size:

Procedure for Particle Size Analysis:

1. Sample Preparation:

Gently mix the sunscreen cream to ensure uniformity.

If the emulsion is too concentrated (turbid or opaque), dilute it with deionized water or the continuous phase (e.g., buffer or surfactant solution) to an appropriate level.

2. Instrument Setup:

Turn on the instrument and allow it to stabilize (as per manufacturer's guidelines).

Select the appropriate measurement parameters:

Dispersant: e.g., water, buffer

Temperature: typically 25 °C

Material refractive index: ~1.45 for oil, ~1.33 for water (adjust depending on your formulation)

3. Loading the Sample:

Fill a clean cuvette (disposable or quartz) with the diluted sample (~1 mL).

Ensure there are no bubbles in the sample.

Insert the cuvette into the instrument properly.

4. Measurement:

Run the measurement in triplicate to ensure reproducibility.

The instrument will measure:

Z-average particle size (intensity-weighted mean size)

Polydispersity Index (PDI) – a measure of size distribution

5. Data Interpretation:

Z-average size: Should ideally be in the 500 nm-5 μm range for Sunscreen Cream.

PDI values:

< 0.1: Monodisperse and stable

0.1–0.3: Moderate polydispersity

> 0.3: High polydispersity, less stable.

14. Determination of Stability Study:

- **Prepare the Sunscreen cream formulation** in its final container (e.g., tube or jar).
- **Label the samples** properly with batch number, date, and test conditions.
- **Divide the samples** into different groups for storage under various accelerated conditions.
- **Store the samples** under the following **accelerated conditions** (commonly used):

45 ± 2°C / 60 ± 5% RH (Relative Humidity)

50 ± 2°C / 75 ± 5% RH (Relative Humidity

Refrigerated condition: 4 ± 2°C

Photostability chamber: to assess light exposure effects

- **Keep the samples** in stability chambers with controlled temperature and humidity.
- **Evaluate the samples** at specific time intervals (e.g., 0, 1, 2, 3, and 6 months).
- **Test the following parameters** at each interval:
    1. **Physical appearance** (color, odor, consistency, Texture**)**
    2. **pH**
    3. **Viscosity (Brookfield viscometer)**
    4. **Phase separation**

- **Compare the results** over time to detect any degradation or changes in quality. **Conclude the stability** of the formulation based on acceptable limits defined by regulatory or internal guidelines.

Result

1. **Physical Evaluation:**

Physical Characteristics	Evaluation of Sunscreen
Color	White
Odor	Odorless
Consistency	Semi-solid
Spreadability	+++
Texture	++++
Smoothness	+++
After feel	S
Homogeneity	Homogeneous
Viscosity	+++
Type of smear	NG

Removal	ES

+: Little, ++: Moderate, +++: Much, ++++: Very much, S: Soft, NG: Non greasy, ES: Easy

Table no. 9 Physical Evaluation

2. Determination of pH:

The pH of the sunscreen cream formulations was determined using a calibrated digital pH meter by preparing a 10% w/v dispersion in deionized water. The optimized formulation exhibited a pH of 7.00, indicating good compatibility with skin application.

Fig no. 1 pH Meter

Measurement	pH
1st	7.00
2nd	6.98
3rd	7.00

Table No10. Determination of pH

3. Determination of Viscosity:

The viscosity of sunscreen cream was determine by Brookfield viscometer **(Model No – D 220).**

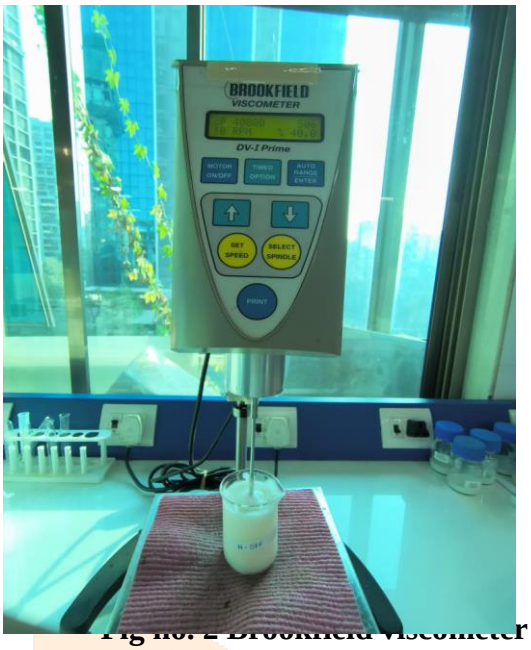

Fig no. 2 Brookfield viscometer

The sunscreen cream exhibited **shear-thinning behavior**, ensuring easy spreadability during application and good consistency at rest. The viscosity of the formulation was found to be **40,000 cps**.

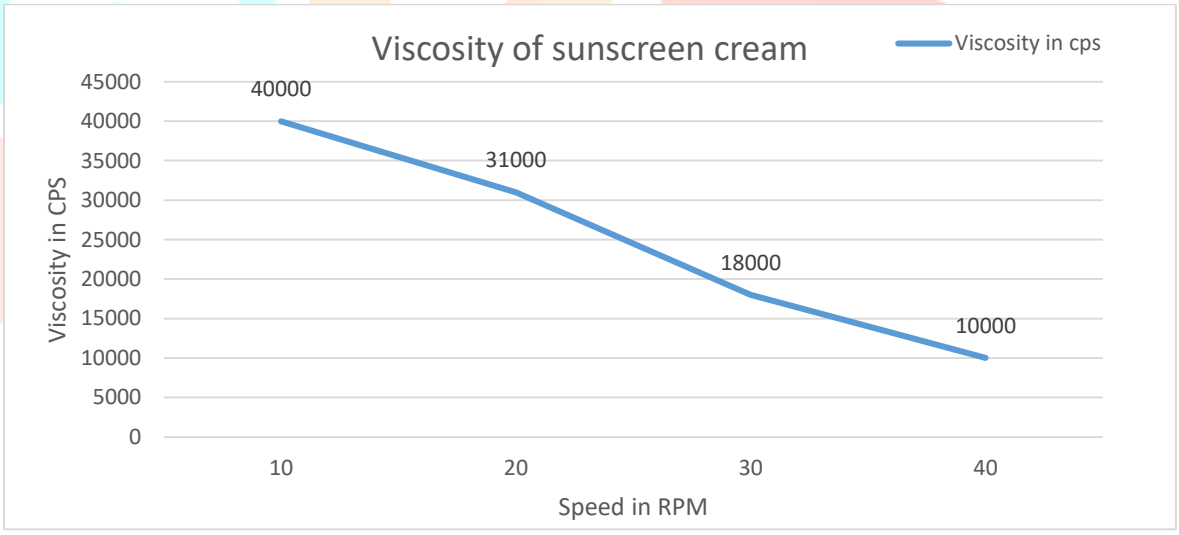

Fig no. 3 Viscosity of sunscreen

4. **Texture Analysis of Sunscreen Cream:**

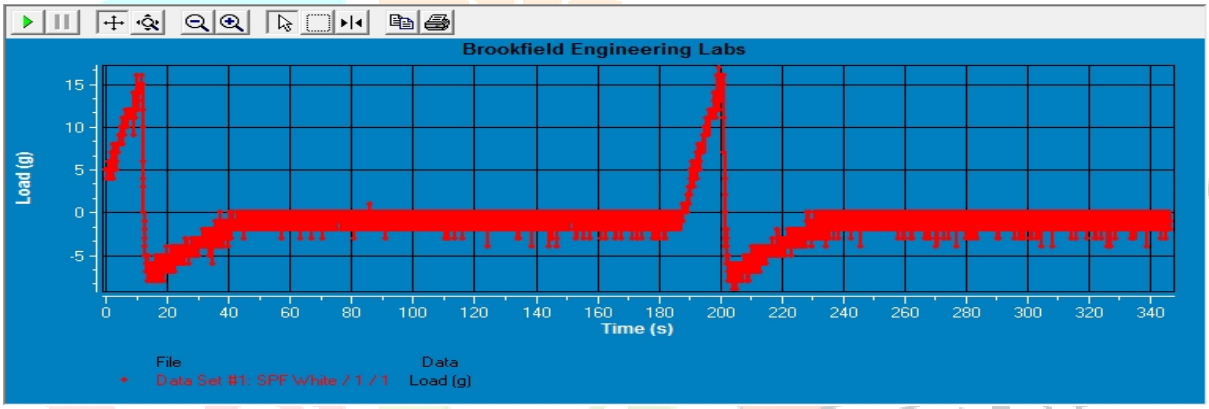

Fig no. 4 CT3 Brookfield Texture Analyzer

Fig no.5 Texture Analysis graph

TexturePro CT V1.3 Build 15 Brookfield Engineering Labs, Inc.

DATA REPORT

Sample Description

Product Name: SPF White Notes:
Batch Name: 1
Sample: 1
Dimensions:
Shape: Block
Length: 0.00 mm
Width: 0.00 mm
Depth: 0.00 mm

Test Method

Test Date: 14-03-2026 Test Time: 16:35:59
Test Type: TPA Recovery Time: 0.00 min
Target: 6.0 mm Same Trigger: True
Hold Time: 0.00 min Pretest Speed: 2 mm/s
Trigger Load: 7 g Data Rate: 20 points/sec
Test Speed: 0.5 mm/s Probe: TA3/100
Return Speed: 0.5 mm/s Fixture: TA-RT-KI
# of Cycles: 2 Load Cell: 10000g

Results

Hardness Cycle 1: 16 g
Hardness Work Cycle 1: 0.6 mJ
Adhesiveness: 1.1 mJ
Cohesiveness: 0.04

Parameter	Result	Standard	Meaning
Hardness (10-15 sec)	16g	10-150g	Cream is soft & Spreadable.
Hardness work	0.6 mJ	0.1-20 mJ	Energy required for compression. (Easy deformable structure).
Adhesiveness (15-40 sec below zero)	1.1 mJ	0.1-10 mJ	Cream has low stickiness & good skin feel.
Cohesiveness(200 sec)	0.04	0.01-0.8	Low recovery & product Behaves like light cream structure

Table no. 11 Texture Analysis Result

5. Determination of Spreadability:

The spreadability of the sunscreen cream was determined by the slide-slip method and was found to be 8.3 g·cm/sec, indicating good spreadability and ease of application. This value suggests that the formulation possesses appropriate consistency, ensuring uniform skin coverage and effective contact with the skin surface.

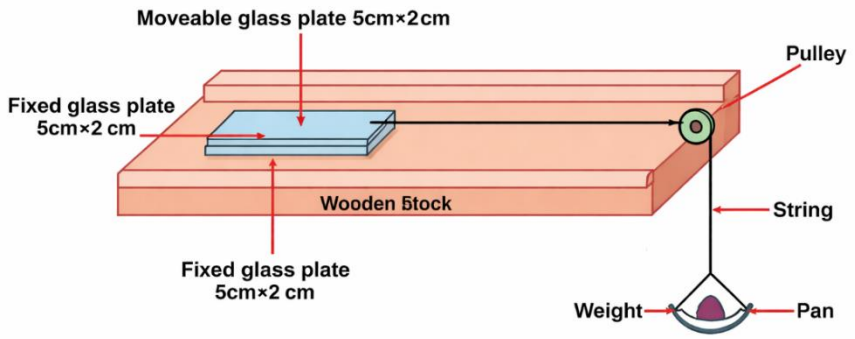

Fig no.6 Spreadability System

6. **Determination of phase separation (Centrifugation):**

Fig no.7 Remi medico plus

The sunscreen cream was subjected to centrifugation at **3000 rpm for 18 minutes** to evaluate its physical stability. **No phase separation was observed**, indicating that the formulation possessed good emulsion stability and maintained its structural integrity under stress conditions.

Fig no. 8 Tube after centrifuge

Days	Centrifugation at RPM	Observation
Day-9	3000	No separation/ sedimentation
Day-15	3000	No separation/ sedimentation
Day-30	3000	No separation/ sedimentation

Table No 12 of phase separation (Centrifugation):

7. **Determination of SPF**

The **SPF of the sunscreen cream** was determined using a **UV–Visible spectrophotometer** and calculated by the **Mansur equation**. The absorbance of the formulation was measured over the UV range, and a graph was plotted with **absorbance on the Y-axis and wavelength on the X-axis** to evaluate its photoprotective efficacy.

Wavelength (nm)	Absorbance
290	0.975
295	0.862
300	0.650
305	0.585
310	0.439
315	0.315
320	0.288

Table no. 13 Absorbance value of 20 ppm.

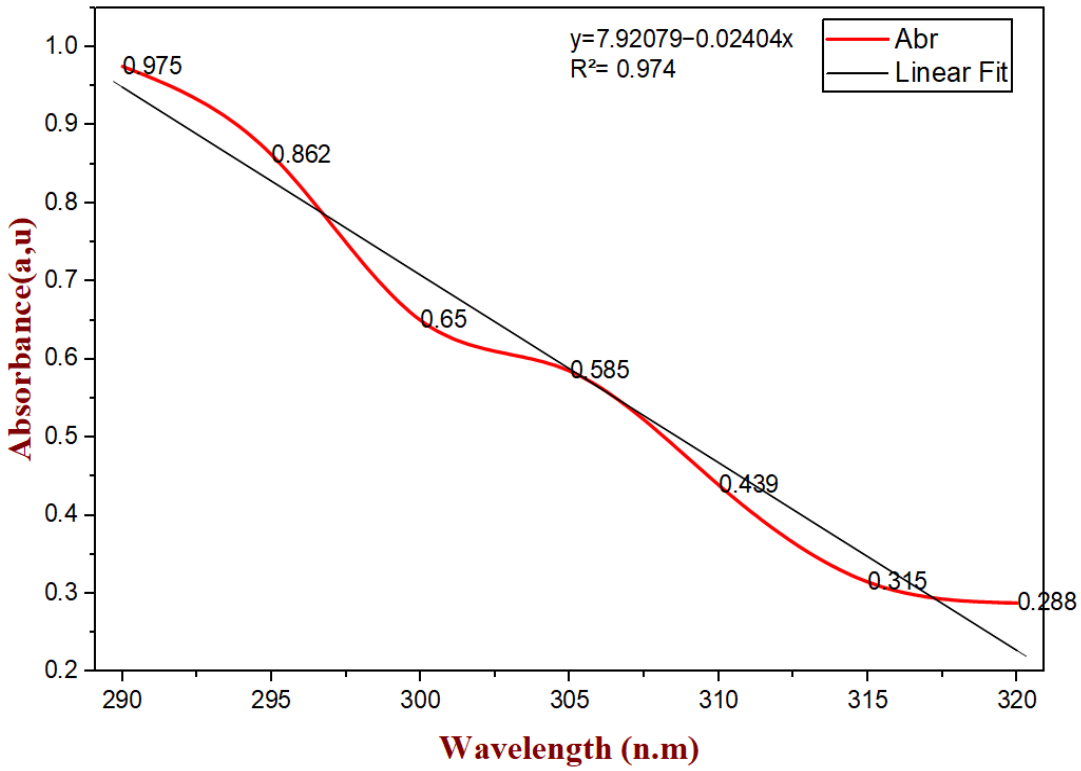

Fig no. 9 Absorbance graph of Sunscreen

λ (nm)	EE×I	Abr	EE×I×Abr
290	0.015	0.975	0.014
295	0.0817	0.862	0.070
300	0.2874	0.650	0.186
305	0.3278	0.585	0.191
310	0.1864	0.439	0.081
315	0.0839	0.315	0.0264
320	0.018	0.288	0.005
			∑ 0.5734

Table no. 14 Normalized product function used in the calculation of SPF.

Where:
EE (l) – erythemal effect spectrum, **I (l)** –solar intensity spectrum, **Abs (l**)- absorbance of sunscreen product, **CF** – correction factor (= 10).

$$SPF = CF \times \sum_{320}^{290} \text{EE}(\lambda).\text{I}(\lambda).\text{Abs}(\lambda)$$

The absorbance value was added in Mansur equation.

The actual SPF was calculated using 200 ppm solution, for get the better accuracy of result, this solution was diluted in 20 ppm. SPF was calculated and result was converted for 200ppm.

Calculation,

SPF (20ppm) = 10 × 0.5734 =5.734

SPF (200ppm) = 10 × 5.734 =57.34

The Sun protection factor (SPF) of Sunscreen cream was found to be 57.34.

8. **Determination of particle size:**

The particle size analysis revealed a **Z-average particle size of 976 nm** with a major intensity peak at **645.6 nm (100%)**, indicating a uniform particle distribution. The **PDI value of 0.312** suggested moderate size uniformity and good formulation homogeneity, while the **intercept value of 0.961** confirmed the reliability and quality of the measurement.

Results

		Size (d.nm):	% Intensity:	St Dev (d.n...
Z-Average (d.nm): 976	Peak 1:	645.6	100.0	58.18
PdI: 0.312	Peak 2:	0.000	0.0	0.000
Intercept: 0.961	Peak 3:	0.000	0.0	0.000

Result quality : Good

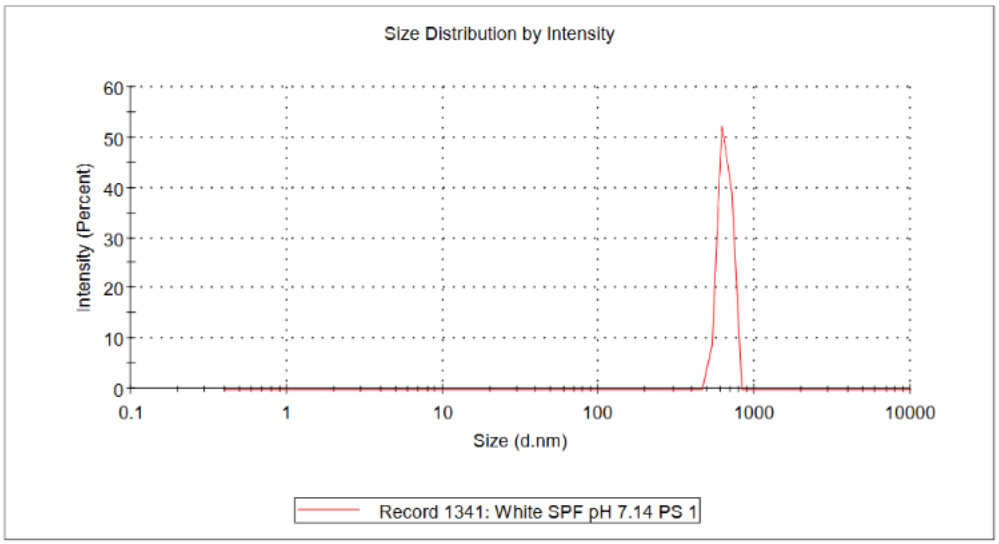

Fig no. 9 Particle size graph

9. **Determination of Stability Study:**

The sunscreen cream exhibited **excellent stability** under accelerated storage conditions, with no significant changes in appearance, pH, viscosity, texture, or phase separation. These results indicate that the formulation maintained its physical and chemical integrity, confirming its suitability for long-term storage and effective performance.

STABILITY REPORT							
NAME OF PRODUCT:	N-SPF		**STABILITY STATUS:**		**PASS**	**FAIL**	**CLOSED**
BATCH CODE:	White SPF - 21						
STABILITY PERIODE	1 MONTH		**OVERALL REMARKS:** THE OVERALL SAMPLE WAS FOUND TO BE OK AS COMPARED TO DAY ONE.				
PROJECT OWNER	Sanket Patil						
ABBREVIATIONS	**D=DAY**	**NA=NOT APPLICABLE**	**M=MONTH**	**NF=NOT FOUND**	**RT=ROOM TEMPERATURE**		
PARAMETERS	**45 DEG C**						
DAYS	**D1**	**D3**	**D6**	**D9**	**D12**	**D15**	**D30**
DATE	20.11.25	23.11.25	26.11.25	29.11.25	02.12.26	05.12.26	20.12.26
COLOUR	WHITE	WHITE	WHITE	WHITE	WHITE	WHITE	WHITE
TEXTURE/APPEARANCE	UNIFORM CREAM	UNIFORM CREAM	UNIFORM CREAM	UNIFORM CREAM	UNIFORM CREAM	UNIFORM CREAM	UNIFORM CREAM
VISCOSITY	40000 cps	40000 cps	40000 cps	40000cps	40000 cps	40000cps	40000cps
pH	7.2	6.99	7.00	7.00	7	6.99	7.02
PHASE SEPERATION	NF	NF	NF	NF	NF	NF	NF
PRECIPITATION OF INGREDINETS	NF	NF	NF	NF	NF	NF	NF
SUSPENSION	NF	NF	NF	NF	NF	NF	NF
CENTRIFUGE AT 3000 RPM FOR 18 MIN	PASS	PASS	PASS	PASS	PASS	PASS	PASS
PERFUME/FLAVOUR	OK	OK	OK	OK	OK	OK	OK
RESULT	PASS	PASS	PASS	PASS	PASS	PASS	PASS
PREPARED BY	SANKET	SANKET	SANKET	SANKET	SANKET	SANKET	SANKET

REMARK	SAMPLE IS OK	SAMPLE IS OK	SAMPLE IS OK	SAMPLE IS OK	SAMPLE IS OK	SAMPLE IS OK	SAMPLE IS OK
CHECKED BY	SANKET	SANKET	SANKET	SANKET	SANKET	SANKET	SANKET

Table no. 15 Stability Report at 45º C.

STABILITY REPORT							
NAME OF PRODUCT:	N-SPF		**STABILITY STATUS:**		**PASS**	**FAIL**	**CLOSED**
BATCH CODE:	White SPF - 21						
STABILITY PERIODE	1 MONTH		**OVERALL REMARKS:** THE OVERALL SAMPLE WAS FOUND TO BE OK AS COMPARED TO DAY ONE.				
PROJECT OWNER	Sanket Patil						
ABBREVIATIONS	**D=DAY**	**NA=NOT APPLICABLE**	**M=MONTH**	**NF=NOT FOUND**	**RT=ROOM TEMPERATURE**		
PARAMETERS	**50 DEG C**						
DAYS	**D1**	**D3**	**D6**	**D9**	**D12**	**D15**	**D30**
DATE	20.11.25	23.11.25	26.11.25	29.11.25	02.12.26	05.12.26	20.12.26
COLOUR	WHITE	WHITE	WHITE	WHITE	WHITE	WHITE	WHITE
TEXTURE/APPEARANCE	UNIFORM CREAM	UNIFORM CREAM	UNIFORM CREAM	UNIFORM CREAM	UNIFORM CREAM	UNIFORM CREAM	UNIFORM CREAM
VISCOSITY	40000 cps	40000 cps	40000 cps	40000 cps	40000 cps	40000 cps	40000 cps
pH	7	6.99	7.01	6.98	7	6.99	7.02
PHASE SEPERATION	NF	NF	NF	NF	NF	NF	NF
PRECIPITATION OF INGREDINETS	NF	NF	NF	NF	NF	NF	NF
SUSPENSION	NF	NF	NF	NF	NF	NF	NF
CENTRIFUGE AT 3000 RPM FOR 18 MIN	PASS	PASS	PASS	PASS	PASS	PASS	PASS
PERFUME/FLAVOUR	OK	OK	OK	OK	OK	OK	OK
RESULT	PASS	PASS	PASS	PASS	PASS	PASS	PASS

PREPARED BY	SANKET	SANKET	SANKET	SANKET	SANKET	SANKET	SANKET
REMARK	SAMPLE IS OK	SAMPLE IS OK	SAMPLE IS OK	SAMPLE IS OK	SAMPLE IS OK	SAMPLE IS OK	SAMPLE IS OK
CHECKED BY	SANKET	SANKET	SANKET	SANKET	SANKET	SANKET	SANKET

Table no. 16 Stability Report at 55º C

STABILITY REPORT							
NAME OF PRODUCT:	N-SPF		**STABILITY STATUS:**		**PASS**	**FAIL**	**CLOSED**
BATCH CODE:	White SPF - 21						
STABILITY PERIODE	1 MONTH		**OVERALL REMARKS:** THE OVERALL SAMPLE WAS FOUND TO BE OK AS COMPARED TO DAY ONE.				
PROJECT OWNER	Sanket Patil						
ABBREVIATIONS	**D=DAY**	**NA=NOT APPLICABLE**	**M=MONTH**	**NF=NOT FOUND**	**RT=ROOM TEMPERATURE**		
PARAMETERS	**5 DEG C**						
DAYS	**D1**	**D3**	**D6**	**D9**	**D12**	**D15**	**D30**
DATE	20.11.25	23.11.25	26.11.25	29.11.25	02.12.26	05.12.26	20.12.26
COLOUR	WHITE	WHITE	WHITE	WHITE	WHITE	WHITE	WHITE
TEXTURE/APPEARANCE	UNIFORM CREAM	UNIFORM CREAM	UNIFORM CREAM	UNIFORM CREAM	UNIFORM CREAM	UNIFORM CREAM	UNIFORM CREAM
VISCOSITY	40000 cps	40000 cps	40000 cps	40000 cps	40000 cps	40000 cps	40000 cps
pH	7	7.3	7.05	6.98	7.1	6.98	7.00
PHASE SEPERATION	NF	NF	NF	NF	NF	NF	NF
PRECIPITATION OF INGREDINETS	NF	NF	NF	NF	NF	NF	NF
SUSPENSION	NF	NF	NF	NF	NF	NF	NF
CENTRIFUGE AT 3000 RPM FOR 18 MIN	PASS	PASS	PASS	PASS	PASS	PASS	PASS

PERFUME/FLAVOUR	OK	OK	OK	OK	OK	OK	OK
RESULT	PASS	PASS	PASS	PASS	PASS	PASS	PASS
PREPARED BY	SANKET	SANKET	SANKET	SANKET	SANKET	SANKET	SANKET
REMARK	SAMPLE IS OK	SAMPLE IS OK	SAMPLE IS OK	SAMPLE IS OK	SAMPLE IS OK	SAMPLE IS OK	SAMPLE IS OK
CHECKED BY	SANKET	SANKET	SANKET	SANKET	SANKET	SANKET	SANKET

Table no. 17 Stability Report at 5º C

Discussion

The present study successfully developed a natural-based broad-spectrum sunscreen cream containing zinc oxide and titanium dioxide as mineral UV filters. The formulation exhibited desirable physicochemical characteristics, including a smooth, homogeneous, non-greasy texture with good spreadability, which are essential attributes for topical sunscreen products.

The optimized formulation showed a pH of 7.00, indicating good skin compatibility, while the viscosity of 40,000 cps and shear-thinning behavior ensured easy application and adequate retention on the skin surface. Texture analysis further confirmed the soft, spreadable nature of the cream with low adhesiveness and satisfactory cohesiveness, contributing to improved user acceptability.

The spreadability value of 8.3 g·cm/sec demonstrated uniform application and effective skin coverage. Furthermore, no phase separation was observed during centrifugation studies, indicating good emulsion stability and proper dispersion of formulation components.

The developed sunscreen cream exhibited a high SPF value of 57.34, demonstrating excellent photoprotective efficacy against ultraviolet radiation. This enhanced protection can be attributed to the synergistic effect of zinc oxide and titanium dioxide, which provide broad-spectrum coverage against both UVA and UVB radiation.

Particle size analysis revealed a Z-average particle size of 976 nm with a PDI of 0.312, indicating good formulation homogeneity and acceptable particle size distribution. Stability studies conducted under different storage conditions showed no significant changes in appearance, pH, viscosity, or phase separation, confirming the physical and chemical stability of the formulation.

Overall, the results indicate that the developed natural-based sunscreen cream possesses excellent photoprotective efficacy, desirable physicochemical properties, and good stability, making it a promising candidate for safe and effective broad-spectrum skin protection.

Conclusion

The present study successfully developed and evaluated a natural-based broad-spectrum sunscreen cream containing zinc oxide and titanium dioxide as mineral UV filters. The formulation exhibited desirable physicochemical properties, including appropriate pH, viscosity, texture, spreadability, and excellent emulsion stability. The developed sunscreen cream demonstrated a high SPF value of 57.34, indicating effective protection against ultraviolet radiation. Particle size analysis confirmed good formulation homogeneity, while accelerated stability studies revealed no significant changes in appearance, pH, viscosity, or phase separation under various storage conditions. Overall, the formulation showed excellent

photoprotective efficacy, stability, and user-friendly characteristics, suggesting its potential as a safe and effective broad-spectrum sunscreen for protection against both UVA and UVB radiation.

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