

Formulation and Evaluation of Herbal Sunscreen Spray Containing Turmeric and Aloe vera Extracts for Enhanced Photoprotection

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Abstract: Excessive exposure to ultraviolet (UV) radiation is one of the major causes of sunburn, premature skin ageing, hyperpigmentation, and skin cancer. The growing concern about the adverse effects of synthetic sunscreen agents has spurred interest in developing herbal-based photoprotective formulations. The present study aimed to formulate and evaluate a herbal sunscreen spray containing natural ingredients, including turmeric and Aloe vera extracts, to enhance photoprotection and skin compatibility.

The herbal sunscreen spray was prepared using turmeric extract, Aloe vera gel, coconut oil, rose water, glycerin, vitamin E, and zinc oxide by employing a simple emulsification technique. The prepared formulation was evaluated for various physicochemical parameters including colour, odour, homogeneity, pH, viscosity, spreadability, irritancy, rancidity, and stability. The type of emulsion was determined by dye test, while the Sun Protection Factor (SPF) was evaluated using the UV spectrophotometric method based on the Mansur equation.

The formulated sunscreen spray showed good homogeneity, acceptable pH, satisfactory spreadability, and no signs of skin irritation or phase separation during stability studies. The formulation exhibited effective photoprotective activity, with a high SPF value, indicating strong UV protection. The presence of natural antioxidants and polyphenolic compounds in turmeric and Aloe vera contributed to enhanced sunscreen activity and improved skin protection.

The study concludes that the developed herbal sunscreen spray is a stable, safe, and effective formulation with potential application as a natural alternative to conventional chemical sunscreens. The formulation may provide broad-spectrum protection with reduced risk of adverse skin reactions and improved consumer acceptability.

Keywords: Herbal sunscreen spray, Turmeric extract, Aloe vera, SPF, Photoprotection, Herbal cosmetics, UV protection, Natural antioxidants

I. INTRODUCTION

Human skin is continuously exposed to environmental stressors, among which ultraviolet (UV) radiation is a major cause of skin damage and photoaging. Ultraviolet radiation is categorised into three major regions based on wavelength: ultraviolet A (UVA, 315–400 nm), ultraviolet B (UVB, 280–315 nm), and ultraviolet C (UVC, 100–280 nm). Among these, UVA and UVB rays are primarily responsible for harmful biological effects on the skin, including erythema, pigmentation, premature ageing, immunosuppression, and skin cancer (World Health Organisation, WHO, 2022).



1.1 Overview of Sunscreens

Sunscreens are topical preparations designed to protect the skin against harmful UV radiation by absorbing, scattering, or reflecting UV radiation. Regular use of sunscreen significantly reduces the risk of sunburn, photoaging, and skin malignancies (American Academy of Dermatology [AAD], n.d.). Sunscreens are available in various dosage forms, including creams, lotions, gels, sticks, and sprays. Among these, sunscreen sprays have gained considerable popularity due to their ease of application, rapid absorption, non-greasy formula, and improved user compliance.

The rising incidence of adverse reactions to synthetic sunscreen agents, including skin irritation, allergic reactions, and environmental concerns, has prompted researchers to explore herbal and naturally derived photoprotective formulations. Herbal sunscreens containing plant extracts rich in flavonoids, polyphenols, carotenoids, and antioxidants have shown promising UV-protective properties and improved safety profiles.

Table 1: Classification of Ultraviolet Radiation and Biological Effects (WHO, 2022).

| UV Region | Wavelength Range | Skin Penetration | Major Biological Effects |
|-----------|------------------|----------------------------|---|
| UVA | 315–400 nm | Deep dermal penetration | Photoaging, pigmentation, oxidative stress |
| UVB | 280–315 nm | Epidermal penetration | Sunburn, DNA damage, skin cancer |
| UVC | 100–280 nm | Absorbed by the atmosphere | Highly harmful but does not reach Earth's surface |

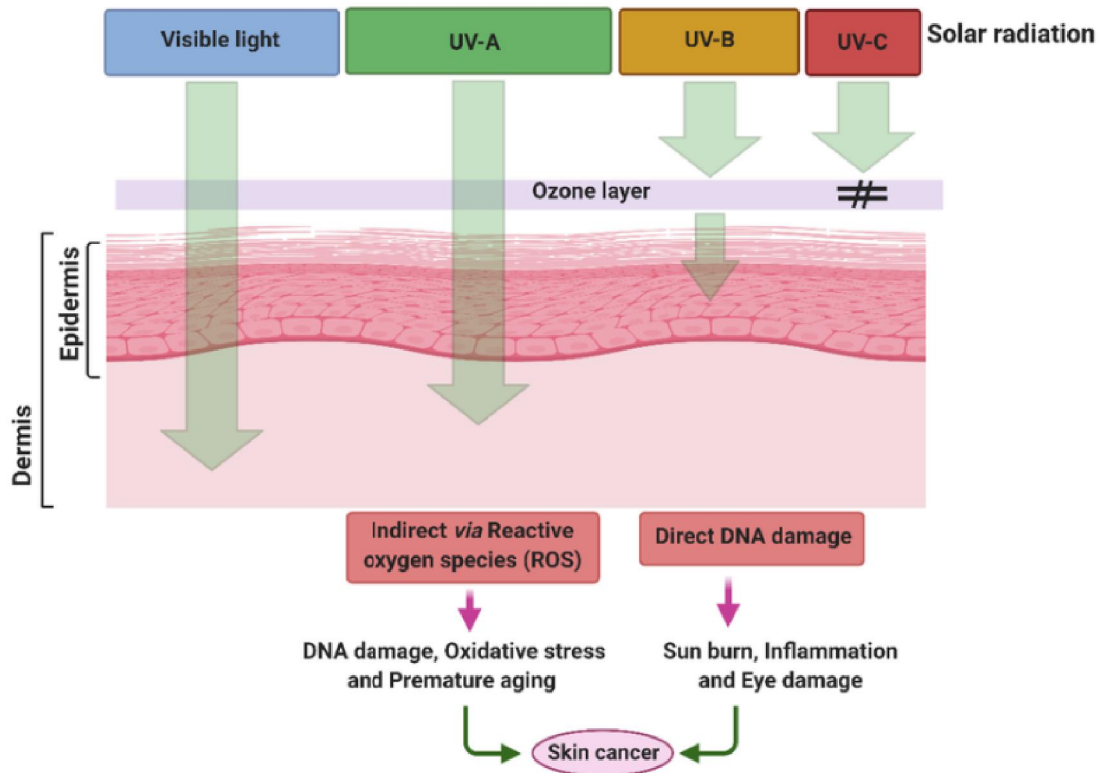


Figure 1: Classification of ultraviolet radiation and its penetration into skin layers.



1.2 Effects of Ultraviolet Radiation on Skin

Exposure to excessive ultraviolet radiation can induce both acute and chronic dermatological disorders. UVB radiation primarily affects the epidermal layer and is responsible for erythema, sunburn, and direct DNA damage. In contrast, UVA radiation penetrates more deeply into the dermis and primarily contributes to oxidative stress, collagen degradation, premature ageing, and immunological alterations (CDC, 2025).

Prolonged UV exposure increases the generation of reactive oxygen species (ROS), which damage cellular proteins, lipids, and nucleic acids. Such oxidative damage accelerates wrinkle formation, pigmentation disorders, and carcinogenesis. According to WHO reports, excessive UV exposure is strongly associated with both melanoma and non-melanoma skin cancers (WHO, 2022).

Table 2: Harmful Effects of UV Radiation on Human Skin

| Type of Damage | UV Radiation Responsible | Clinical Manifestation |
|------------------|--------------------------|-------------------------------|
| Acute Damage | UVB | Sunburn, erythema |
| Chronic Damage | UVA | Wrinkles, photoaging |
| Oxidative Stress | UVA and UVB | Free radical generation |
| DNA Damage | UVB | Mutation and carcinogenesis |
| Pigmentation | UVA | Hyperpigmentation and tanning |

MECHANISM OF UV-INDUCED SKIN DAMAGE & OXIDATIVE STRESS.

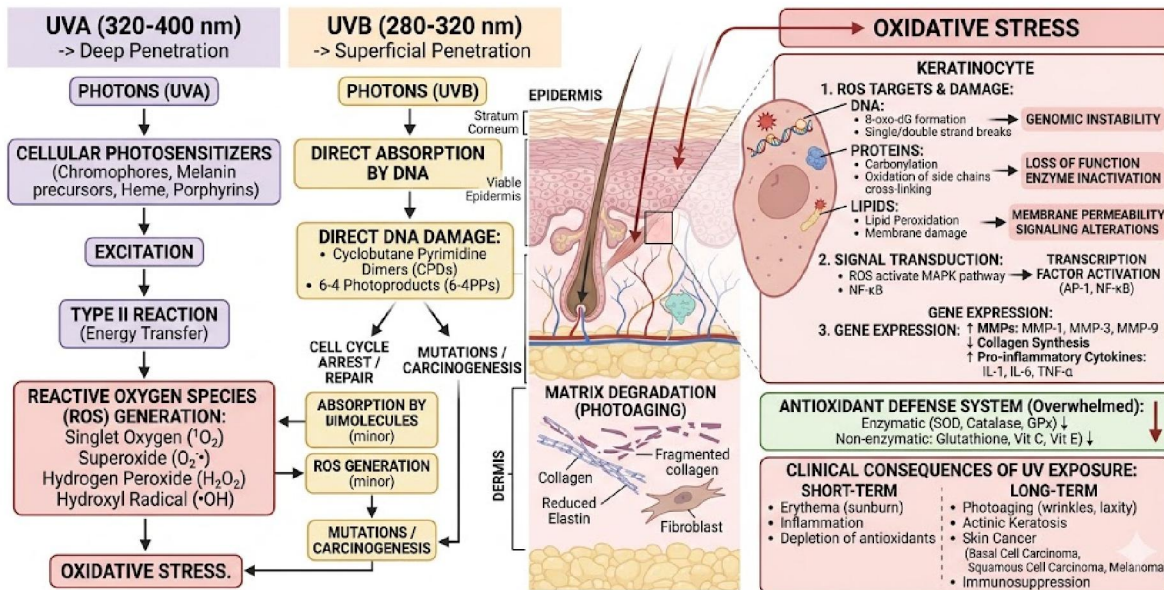


Figure 2: Mechanism of UV-induced skin damage and oxidative stress.

1.3 Classification of Sunscreens

Sunscreens are generally classified into physical (mineral) sunscreens and chemical sunscreens based on their mechanism of action.

Physical sunscreens, also known as inorganic sunscreens, contain mineral agents such as zinc oxide and titanium dioxide that reflect and scatter UV radiation from the skin surface. These formulations provide broad-spectrum protection and are generally considered safe for sensitive skin (WHO, n.d.).



Chemical sunscreens contain organic compounds such as avobenzone, oxybenzone, octisalate, and homosalate that absorb UV radiation and convert it into heat energy. Although these agents provide effective protection and cosmetically elegant formulations, concerns have been raised regarding skin irritation, systemic absorption, and ecological toxicity.

Herbal sunscreens utilise naturally occurring phytoconstituents with antioxidant and UV-absorbing properties. Plant-derived compounds, including flavonoids, tannins, curcumin, polyphenols, and carotenoids, have demonstrated significant photoprotective potential due to their free radical scavenging activity.

Table 3: Comparison Between Physical, Chemical and Herbal Sunscreens

| Type | Mechanism | Common Ingredients | Advantages | Limitations |
|--------------------|-------------------------------|--------------------------------|----------------------------|--------------------------------------|
| Physical Sunscreen | Reflect/scatter UV rays | Zinc oxide, titanium dioxide | Broad-spectrum protection | Whitening effect |
| Chemical Sunscreen | Absorb UV radiation | Avobenzone, oxybenzone | Better cosmetic appearance | Skin irritation potential |
| Herbal Sunscreen | Antioxidant and UV absorption | Turmeric, Aloe vera, green tea | Safer and eco-friendly | Lower stability in some formulations |

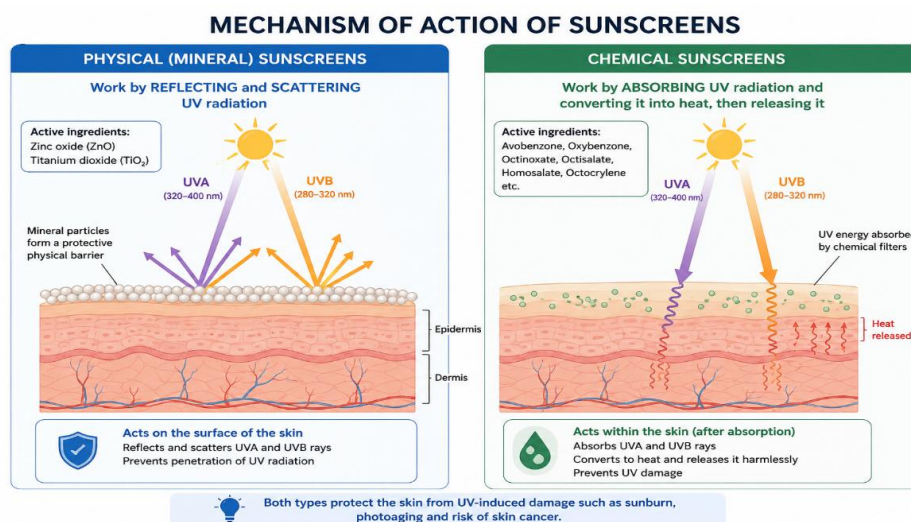


Figure 3: Mechanism of action of physical and chemical sunscreens.

1.4 Need for Herbal Sunscreen Formulations

Recently, there has been a growing consumer preference for herbal and natural cosmetic products due to their perceived safety, biodegradability, and reduced side effects. Herbal sunscreen formulations are enriched with phytochemicals that exhibit antioxidant, anti-inflammatory, and photoprotective activities. Natural antioxidants help neutralise free radicals generated by UV exposure, thereby reducing oxidative stress and preventing skin damage.

Turmeric (*Curcuma longa*) contains curcumin, a bioactive polyphenolic compound known for its antioxidant, anti-inflammatory, and UV-protective properties. Curcumin has demonstrated the ability to reduce UV-induced oxidative damage and improve skin protection. Aloe vera possesses moisturising, soothing, wound-healing, and anti-inflammatory activities that improve skin hydration and reduce irritation caused by sun exposure.

The combination of turmeric and Aloe vera in sunscreen formulations may provide synergistic photoprotective effects while improving formulation safety and skin compatibility.



1.5 Advantages of Sunscreen Spray Dosage Form

Sunscreen sprays offer several advantages over conventional creams and lotions. Spray formulations ensure uniform application, rapid drying, and improved spreadability. They are particularly suitable for application over large body surfaces and difficult-to-reach areas such as the back and shoulders. Spray-based sunscreens are lightweight, non-sticky, and cosmetically acceptable, which enhances patient compliance and convenience during outdoor activities. Additionally, moisturizing spray formulations containing glycerin, Aloe vera, and vitamin E improve skin hydration while providing photoprotection. The incorporation of natural oils and antioxidants further enhances skin nourishment and reduces transepidermal water loss.

Table 4: Advantages of Sunscreen Spray Formulations

| Property | Benefit |
|----------------------|-------------------------------|
| Easy application | Convenient and time-saving |
| Non-greasy texture | Better cosmetic acceptability |
| Uniform distribution | Improved coverage |
| Fast absorption | Reduced stickiness |
| Portable dosage form | Suitable for outdoor use |
| Moisturizing effect | Prevents skin dryness |

1.6 Mechanism of Photoprotection

Photoprotection refers to the prevention or reduction of UV-induced skin damage through physical barriers, UV absorption, antioxidant activity, and DNA repair mechanisms. Sunscreens protect the skin by reducing the penetration of harmful UV rays into deeper skin layers. Physical filters scatter UV radiation, whereas chemical filters absorb UV energy and convert it into less harmful forms of heat.

Herbal ingredients contribute additional photoprotective benefits through antioxidant activity. Polyphenols and flavonoids present in herbal extracts neutralize reactive oxygen species generated during UV exposure and reduce inflammatory responses.

II. LITERATURE REVIEW

The increasing prevalence of ultraviolet (UV)-induced skin disorders has accelerated research on safer and more effective sunscreen formulations. In recent years, herbal sunscreen preparations have gained considerable attention because of their antioxidant activity, reduced toxicity, biodegradability, and improved skin compatibility. Various medicinal plants rich in flavonoids, polyphenols, carotenoids, and vitamins have demonstrated significant photoprotective properties against UVA and UVB radiation.

2.1 Herbal Sunscreen Research Trends

The use of plant-derived bioactive compounds in sunscreen formulations has emerged as an important area of pharmaceutical and cosmetic research. Natural compounds exhibit UV absorption properties along with antioxidant and anti-inflammatory activities that help prevent oxidative stress induced by UV exposure.

Velasco et al. (2008) reported that natural bioactive products can enhance broad-spectrum UV protection while reducing the concentration of synthetic UV filters in formulations. The study emphasized the growing interest in eco-friendly and biologically safer sunscreen systems (Velasco et al., 2008).

Similarly, Ashawat et al. (2008) reviewed the role of medicinal plants such as Aloe vera, green tea, cucumber, basil, jojoba, and almond oil in herbal sunscreen preparations and concluded that herbal ingredients provide both photoprotective and skin nourishing effects.

Table 5: Major Herbal Ingredients Reported in Sunscreen Formulations

| Herbal Ingredient | Major Phytoconstituents | Reported Activity |
|-------------------|-------------------------|---------------------------------|
| Aloe vera | Aloin, aloe-emodin | Moisturizing, anti-inflammatory |



| | | |
|--------------------------------------|------------------------|-------------------------------------|
| Turmeric (<i>Curcuma longa</i>) | Curcumin | Antioxidant, UV protection |
| Green tea | Catechins, polyphenols | Free radical scavenging |
| Tomato extract | Lycopene | Photoprotection |
| Licorice | Glabridin | Skin brightening, anti-inflammatory |
| Rosemary | Rosmarinic acid | Antioxidant activity |

2.2 Natural UV Filters and Their Applications

Natural UV filters are plant-derived compounds capable of absorbing or neutralizing ultraviolet radiation. Polyphenolic compounds, flavonoids, tannins, and carotenoids are widely recognized for their UV-protective potential because of their conjugated double-bond structures and antioxidant properties.

Tabrizi et al. (2003) stated that natural raw materials with UV absorption capabilities are increasingly preferred in sunscreen development because they provide photoprotection with fewer adverse effects compared to synthetic agents. Plant extracts rich in flavonoids exhibit strong UV absorbance within both UVA and UVB regions, making them suitable candidates for herbal sunscreen formulations.

Curcumin, the principal active component of turmeric, has shown remarkable antioxidant and anti-inflammatory activities. Research indicates that curcumin can inhibit UV-induced oxidative damage and reduce inflammatory responses in skin cells. Aloe vera also plays an important role in topical photoprotective formulations due to its moisturizing, wound-healing, and soothing properties.

Table 6: Natural Phytochemicals with Photoprotective Activity

| Phytochemical | Natural Source | Pharmacological Activity |
|---------------|-----------------|---------------------------------------|
| Curcumin | Turmeric | Antioxidant, anti-inflammatory |
| Lycopene | Tomato | UV-induced oxidative stress reduction |
| Catechins | Green tea | Anti-aging and antioxidant |
| Flavonoids | Various plants | UV absorption |
| Polyphenols | Medicinal herbs | Free radical scavenging |

2.3 Polyphenols and Photoprotective Activity

Polyphenolic compounds are considered one of the major classes of phytochemicals responsible for herbal photoprotection. These compounds possess antioxidant properties that help neutralize reactive oxygen species generated by UV radiation exposure.

Movileanu et al. (2000) demonstrated that polyphenolic compounds exhibit several pharmacological activities including antioxidant, anti-inflammatory, antitumor, antibacterial, and free radical scavenging properties. These biological effects contribute significantly to skin protection against photooxidative damage.

F'guyer et al. (2003) further reported that botanical compounds such as curcumin, tea polyphenols, resveratrol, and silymarin possess anticarcinogenic and antimutagenic activities that may help prevent UV-induced skin carcinogenesis.

Velasco et al. (2008) suggested that the structural similarities between flavonoids and synthetic UV filters contribute to their photoprotective properties. These compounds not only absorb UV radiation but also stabilize free radicals produced during photooxidative stress.

Table 7: Biological Activities of Polyphenolic Compounds

| Biological Activity | Mechanism |
|----------------------------|-------------------------------------|
| Antioxidant action | Neutralization of free radicals |
| Anti-inflammatory activity | Reduction of inflammatory mediators |
| Anticarcinogenic effect | Prevention of DNA mutation |
| UV absorption | Protection against UVA/UVB rays |



Anti-aging effect

Prevention of collagen degradation

2.4 Previous Studies on Herbal Sunscreen Formulations

Several researchers have formulated and evaluated herbal sunscreen creams, lotions, and gels using plant extracts and natural oils. Herbal formulations have demonstrated acceptable physicochemical stability, improved SPF values, and better skin compatibility.

Baby et al. (2006) developed a UV spectrophotometric method for determining flavonoid content in semisolid pharmaceutical formulations and reported significant UV absorbance characteristics in plant-derived extracts. Their work highlighted the importance of phytoconstituents in SPF enhancement.

Sonawane et al. (2021) formulated and evaluated herbal sunscreen cream containing natural extracts and reported satisfactory SPF values along with good stability and spreadability characteristics.

Similarly, Rashid et al. (2012) developed a herbal sunscreen lotion and concluded that herbal formulations containing antioxidant-rich plant extracts exhibited effective UV protection with reduced skin irritation.

2.5 Research Gap Identified

Although numerous herbal sunscreen formulations have been investigated, several limitations remain regarding formulation stability, SPF optimization, consumer acceptability, and dosage form selection. Most studies have focused on creams and lotions, whereas comparatively limited research has been conducted on herbal sunscreen spray formulations.

Furthermore, many synthetic sunscreen products are associated with skin irritation, allergic reactions, and environmental concerns. Therefore, there remains a need to develop stable, non-greasy, user-friendly, and effective herbal sunscreen sprays containing natural antioxidants and UV-protective agents.

The present study focuses on the formulation and evaluation of a herbal sunscreen spray containing turmeric and Aloe vera extracts to provide enhanced photoprotection, improved cosmetic acceptability, and reduced adverse effects compared to conventional synthetic sunscreen formulations.

III. AIM AND OBJECTIVES

3.1 Aim

- To formulate and evaluate a herbal sunscreen spray containing turmeric and Aloe vera extracts for enhanced photoprotective activity and improved skin compatibility.

3.2 Objectives

- To develop a stable herbal sunscreen spray using natural ingredients with UV-protective properties.
- To prepare the formulation using turmeric extract, Aloe vera, coconut oil, rose water, glycerin, vitamin E, and zinc oxide.
- To evaluate the physicochemical properties of the formulated sunscreen spray.
- To determine the homogeneity, pH, viscosity, spreadability, and emulsion type of the formulation.
- To assess the irritancy and safety profile of the prepared herbal sunscreen spray.
- To evaluate the Sun Protection Factor (SPF) of the formulation using UV spectrophotometric analysis.

$$SPF = CF \times \sum EE(\lambda) \times I(\lambda) \times Abs(\lambda)$$
- To study the short-term stability of the formulation under room temperature storage conditions.
- To investigate the role of herbal antioxidants in enhancing photoprotection and reducing UV-induced skin damage.
- To develop a non-greasy, easy-to-apply sunscreen spray with improved cosmetic acceptability and user compliance.
- To explore the potential of herbal sunscreen formulations as safer alternatives to synthetic sunscreen products.



IV. MATERIALS AND METHODS

4.1 Materials Used

The materials used to formulate the herbal sunscreen spray included turmeric extract, Aloe vera gel, coconut oil, rose water, glycerin, vitamin E capsules, zinc oxide, distilled water, and essential oil. All ingredients used in the formulation were of pharmaceutical or cosmetic grade and were procured from local suppliers.

Table 8: Materials Used in Herbal Sunscreen Spray Formulation

| S. No. | Material | Category | Role in Formulation |
|--------|------------------|--------------------------|-------------------------------------|
| 1 | Turmeric extract | Herbal active | Antioxidant and UV protective agent |
| 2 | Aloe vera gel | Herbal active | Moisturizer and soothing agent |
| 3 | Zinc oxide | Physical sunscreen agent | UV radiation blocker |
| 4 | Coconut oil | Emollient | Skin conditioning agent |
| 5 | Rose water | Vehicle | Cooling and fragrance agent |
| 6 | Glycerin | Humectant | Moisturizing agent |
| 7 | Vitamin E | Antioxidant | Skin protection and stabilization |
| 8 | Distilled water | Solvent | Aqueous phase preparation |
| 9 | Essential oil | Fragrance agent | Improves acceptability |

4.2 Plant Materials and Excipients

Turmeric (*Curcuma longa*) was selected because of its curcumin content, which possesses antioxidant, anti-inflammatory, and UV-protective properties. Aloe vera was incorporated for its moisturising, soothing, and wound-healing activity. Zinc oxide was used as a physical sunscreen agent because of its broad-spectrum UV protection capability.

Glycerin and coconut oil were incorporated to improve skin hydration and formulation spreadability. Vitamin E was added as an antioxidant to enhance formulation stability and minimise oxidative degradation.

Table 9: Functional Role of Herbal Ingredients

| Herbal Ingredient | Major Active Constituent | Functional Property |
|-------------------|--------------------------|---------------------------------|
| Turmeric | Curcumin | Antioxidant and photoprotective |
| Aloe vera | Aloe-emodin | Moisturizing and soothing |
| Coconut oil | Fatty acids | Emollient and skin conditioning |
| Vitamin E | Tocopherol | Antioxidant protection |
| Rose water | Phenolic compounds | Cooling and refreshing effect |

4.3 Preparation of Turmeric Extract

Fresh turmeric rhizomes were collected, cleaned, dried, and powdered. The powdered turmeric was used for the extraction preparation. Approximately the required amount of turmeric powder was added to distilled water in a beaker and heated gently with continuous stirring. The mixture was allowed to stand for 15–20 minutes to facilitate the extraction of active constituents. The extract was then filtered using filter paper to remove insoluble particles, and the filtrate was used for formulation preparation.

The prepared extract was stored in a clean airtight container until further use.

Table 10: Steps Involved in Preparation of Turmeric Extract

| Step | Procedure |
|------|--|
| 1 | Collection and cleaning of turmeric rhizomes |
| 2 | Drying and pulverization into powder |
| 3 | Addition of powder to distilled water |
| 4 | Mild heating and continuous stirring |



| | |
|---|-------------------------------|
| 5 | Steeping for 15–20 minutes |
| 6 | Filtration of extract |
| 7 | Storage in airtight container |

4.4 Formulation of Herbal Sunscreen Spray

The herbal sunscreen spray was prepared using a simple emulsification method involving separate preparation of aqueous and oil phases followed by continuous mixing.

4.4.1 Preparation of Aqueous Phase

A clean beaker was taken and rose water along with distilled water was added. Aloe vera gel and glycerin were then incorporated into the aqueous phase with continuous stirring until a homogeneous mixture was obtained.

4.4.2 Preparation of Oil Phase

In another beaker, coconut oil and vitamin E were mixed thoroughly. Zinc oxide powder was slowly added into the oil phase with continuous stirring to avoid lump formation and ensure uniform dispersion.

4.4.3 Incorporation of Herbal Extract

The prepared turmeric extract was added gradually into the aqueous phase and mixed thoroughly to obtain uniform distribution of herbal constituents.

4.4.4 Final Mixing and Packaging

The oil phase was slowly added into the aqueous phase under continuous stirring for approximately 10–15 minutes to obtain a homogeneous dispersion. Essential oil was added to improve fragrance and consumer acceptability. The final formulation was transferred into a clean spray bottle and stored at room temperature.

Table 11: Formulation Procedure of Herbal Sunscreen Spray

| Step | Procedure |
|------|--|
| 1 | Preparation of aqueous phase |
| 2 | Preparation of oil phase |
| 3 | Addition of turmeric extract |
| 4 | Mixing of oil and aqueous phases |
| 5 | Continuous stirring for homogenization |
| 6 | Addition of fragrance |
| 7 | Transfer into spray bottle |

4.5 Formula Composition Table

The formulation composition of the prepared herbal sunscreen spray is shown below.

Table 12: Formula Composition of Herbal Sunscreen Spray

| Ingredient | Quantity Used | Functional Role |
|------------------|---------------|--------------------------------|
| Turmeric extract | q.s. | Herbal photoprotective agent |
| Aloe vera gel | q.s. | Moisturizer and soothing agent |
| Zinc oxide | q.s. | Physical sunscreen agent |
| Coconut oil | q.s. | Emollient |
| Rose water | q.s. | Vehicle |
| Glycerin | q.s. | Humectant |
| Vitamin E | q.s. | Antioxidant |
| Distilled water | q.s. | Solvent |
| Essential oil | q.s. | Fragrance |



V. EVALUATION PARAMETERS

The prepared herbal sunscreen spray was evaluated for various physicochemical, stability, and performance parameters to determine its quality, safety, homogeneity, and photoprotective effectiveness. The evaluation studies were carried out under laboratory conditions using standard pharmaceutical and cosmetic evaluation procedures.

5.1 Organoleptic Evaluation

Organoleptic evaluation was performed to assess the physical appearance of the formulation, including colour, odour, texture, consistency, and appearance. The prepared sunscreen spray was visually inspected under normal daylight conditions.

The formulation was examined for uniformity, absence of phase separation, and ease of application. Organoleptic characteristics are important because they influence consumer acceptability and product compliance.

Table 13: Organoleptic Evaluation Parameters

| Parameter | Evaluation Criteria |
|--------------|----------------------------------|
| Colour | Visual appearance of formulation |
| Odour | Characteristic fragrance |
| Texture | Smoothness and consistency |
| Appearance | Homogeneity and absence of lumps |
| Sprayability | Ease of spraying and coverage |

5.2 Homogeneity Test

The homogeneity of the prepared formulation was determined by visual inspection and spraying characteristics. The sunscreen spray was checked for uniform dispersion of ingredients, absence of coarse particles, and smooth consistency.

A homogeneous formulation ensures uniform distribution of active ingredients and consistent photoprotective activity throughout application.

Table 14: Homogeneity Evaluation Criteria

| Observation Parameter | Expected Characteristics |
|-----------------------|--------------------------------|
| Uniformity | Even dispersion of ingredients |
| Presence of particles | Absence of aggregates or lumps |
| Consistency | Smooth and uniform |
| Phase separation | No separation observed |

5.3 pH Determination

The pH of the formulation was measured using a calibrated digital pH meter. Approximately 0.5 mL of the sunscreen spray was diluted with distilled water and the electrode was immersed into the sample for pH determination.

The pH of topical formulations should remain within the skin-compatible range to minimize irritation and maintain formulation stability.

Table 15: Importance of pH in Topical Formulations

| pH Range | Effect on Skin |
|----------|------------------------|
| Below 4 | Skin irritation risk |
| 4.5–6.5 | Skin compatible range |
| Above 7 | Dryness and irritation |



5.4 Viscosity Measurement

Viscosity of the herbal sunscreen spray was measured using a Brookfield viscometer at room temperature. Viscosity evaluation helps determine the flow behavior, sprayability, spreadability, and stability of the formulation.

An optimum viscosity is necessary to ensure proper atomization and uniform application of the sunscreen spray.

Table 16: Significance of Viscosity Evaluation

| Parameter | Importance |
|---------------|------------------------------|
| Flow property | Determines spray performance |
| Stability | Prevents phase separation |
| Spreadability | Improves application |
| Consistency | Ensures formulation quality |

5.5 Dye Test for Emulsion Type

The type of emulsion was determined using the dye test method. A small quantity of formulation was mixed with safranin dye and observed under a microscope.

If red-colored globules appeared against a colourless background, the formulation was identified as a water-in-oil emulsion. If colourless globules appeared against a red background, the formulation was considered an oil-in-water emulsion.

Table 17: Interpretation of Dye Test

| Observation | Type of Emulsion |
|---------------------------------------|--------------------|
| Red globules in colourless background | Water-in-oil (W/O) |
| Colourless globules in red background | Oil-in-water (O/W) |

5.6 Spreadability Study

Spreadability determines the ease with which the formulation spreads over the skin surface. A small quantity of the sunscreen spray was applied on a glass surface and spread uniformly to observe its spreading behavior.

Good spreadability ensures better coverage of the skin and improved photoprotective efficiency.

5.7 Rancidity Test

The rancidity test was performed to determine oxidative degradation of oils present in the formulation. Approximately 1 mL of the formulation was mixed with concentrated hydrochloric acid and phloroglucinol solution and observed for colour change.

The absence of pink or red coloration indicated that the formulation remained stable without oxidative rancidity.

Table 18: Interpretation of Rancidity Test

| Observation | Interpretation |
|---------------------------|-----------------------|
| No pink/red colour | Absence of rancidity |
| Pink/red colour formation | Presence of rancidity |

5.8 Irritancy Test

The irritancy test was carried out by applying a small quantity of the formulation on the dorsal surface of the hand. The applied area was observed for redness, itching, inflammation, irritation, or rashes over 24 hours.

The test was performed to evaluate the skin compatibility and safety of the prepared herbal sunscreen spray.

Table 19: Parameters Observed During Irritancy Test

| Observation | Interpretation |
|-------------|----------------------|
| Redness | Skin irritation |
| Itching | Sensitivity reaction |



| | |
|--------------|-----------------------|
| Inflammation | Adverse skin response |
| No reaction | Safe formulation |

5.9 Sun Protection Factor (SPF) Determination

The SPF of the formulation was determined using the UV spectrophotometric method based on the Mansur equation. Approximately 1 g of the formulation was diluted with ethanol and ultrasonicated. The solution was filtered and absorbance values were measured in the wavelength range of 290–320 nm at 5 nm intervals using a UV-visible spectrophotometer.

The SPF value was calculated using the Mansur equation.

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

Where:

CF- Correction factor

EE(λ)- Erythema effect spectrum

I(λ)- Solar intensity spectrum

Abs(λ)- Absorbance of sample

Wavelength Range Used for SPF Determination:

| Wavelength (nm) | UV Region |
|-----------------|-----------------------|
| 290–315 | UVB |
| 315–320 | UVA transition region |

5.10 Short-Term Stability Studies

Short-term stability studies were carried out by storing the prepared formulations at room temperature for a specified period. During the storage period, the formulations were periodically evaluated for pH, homogeneity, colour, consistency, appearance, and phase separation.

Stability studies help determine the shelf stability and physical integrity of the formulation under normal storage conditions.

Table 20: Parameters Evaluated During Stability Studies

| Parameter | Purpose |
|------------------|-------------------------------|
| pH | Stability assessment |
| Appearance | Detection of physical changes |
| Homogeneity | Uniformity evaluation |
| Consistency | Texture stability |
| Phase separation | Emulsion stability |

VI. RESULTS

The formulated herbal sunscreen spray containing turmeric extract and Aloe vera was evaluated for various physicochemical parameters, SPF determination, homogeneity, stability, and skin compatibility. The formulation exhibited satisfactory physical appearance, acceptable stability, and promising photoprotective activity.

6.1 Organoleptic Characteristics

The prepared herbal sunscreen spray was visually examined for colour, odour, texture, consistency, and appearance. The formulation showed a smooth and uniform consistency with acceptable cosmetic appearance. No phase separation or aggregation of ingredients was observed.



Table 21: Organoleptic Characteristics of Herbal Sunscreen Spray

| Parameter | Observation |
|------------------|-------------------------------|
| Colour | Light yellow |
| Odour | Pleasant characteristic odour |
| Appearance | Uniform and homogeneous |
| Texture | Smooth and non-greasy |
| Sprayability | Good and uniform |
| Phase separation | Not observed |

The formulation demonstrated good sprayability and produced a uniform film over the applied surface. The presence of Aloe vera and glycerin contributed to improved moisturizing properties and smooth texture.

6.2 Physicochemical Evaluation Results

The prepared formulation was subjected to physicochemical evaluation including pH determination, homogeneity, viscosity, spreadability, dye test, irritancy, and rancidity testing.

The pH of the formulation was found to be within the acceptable range for topical application, indicating compatibility with skin physiology. The formulation showed good homogeneity without visible lumps or coarse particles. Viscosity was appropriate for spray application and ensured ease of spreading over the skin surface.

Table 22: Physicochemical Evaluation of Herbal Sunscreen Spray

| Evaluation Parameter | Observation |
|----------------------|--------------------------------|
| Homogeneity | Good |
| Texture | Smooth |
| pH | Skin compatible |
| Viscosity | Suitable for spray application |
| Spreadability | Good |
| Emulsion type | Oil in water (O/W) |
| Rancidity test | Negative |
| Irritancy test | No irritation observed |

The dye test confirmed that the formulation was an oil-in-water emulsion, which contributes to better spreadability and reduced greasiness. The irritancy test showed absence of redness, itching, or inflammation after topical application, suggesting good skin compatibility.

Table 23: Interpretation of Evaluation Tests

| Test | Result Interpretation |
|------------------|-----------------------------------|
| Homogeneity test | Uniform dispersion achieved |
| Dye test | Stable O/W emulsion formed |
| Irritancy test | Safe for topical use |
| Rancidity test | No oxidative degradation detected |

6.3 SPF Evaluation Results

The Sun Protection Factor (SPF) of the prepared formulation was evaluated using the UV spectrophotometric method based on the Mansur equation. The formulation exhibited significant absorbance within the UVB region, indicating effective photoprotective activity.

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

The calculated SPF value of the prepared herbal sunscreen spray was found to be approximately 24.888, indicating promising sunscreen efficacy against ultraviolet radiation.



Table 24: SPF Evaluation Result

| Parameter | Observation |
|--------------------|------------------------------|
| Method used | UV spectrophotometric method |
| Wavelength range | 290–320 nm |
| Correction factor | 10 |
| SPF value obtained | 24.888 |

The obtained SPF value suggests that the herbal sunscreen spray provided moderate to high photoprotection against UV-induced skin damage. The antioxidant constituents present in turmeric and Aloe vera may have contributed to enhanced UV protective activity.

6.4 Stability Study Results

Short-term stability studies were performed at room temperature to evaluate the physical stability of the prepared formulation. During the study period, the formulation was periodically observed for changes in colour, pH, homogeneity, consistency, and phase separation.

No significant changes were observed in the physical appearance or consistency of the formulation during storage. The formulation remained stable throughout the study period.

Table 25: Short-Term Stability Study Observations

| Parameter Evaluated | Observation During Storage |
|---------------------|----------------------------|
| Colour | No significant change |
| Appearance | Stable |
| Homogeneity | Maintained |
| Consistency | Unchanged |
| Phase separation | Not observed |
| pH | Stable |

The absence of phase separation and maintenance of consistency indicated good emulsion stability. The formulation remained physically stable under normal storage conditions.

6.5 Comparative Analysis with Marketed Formulation

The prepared herbal sunscreen spray was compared with conventional marketed sunscreen formulations based on texture, spreadability, greasiness, and photoprotective activity. The herbal formulation demonstrated satisfactory cosmetic acceptability and effective SPF value with reduced greasiness.

Table 26: Comparative Analysis of Herbal and Marketed Sunscreen Formulation

| Parameter | Herbal Sunscreen Spray | Conventional Marketed Sunscreen |
|---------------------|------------------------|---------------------------------|
| Texture | Smooth and non-greasy | Slightly greasy |
| Spreadability | Good | Moderate |
| Skin irritation | Not observed | May occur in sensitive skin |
| Photoprotection | Effective | Effective |
| Herbal constituents | Present | Generally absent |
| Moisturizing effect | Good | Moderate |

The prepared formulation showed improved consumer-friendly characteristics because of its lightweight texture, herbal composition, and ease of application. The inclusion of natural antioxidants and moisturizing agents enhanced the overall quality and acceptability of the formulation.



VIII. DISCUSSION

The present study focused on the formulation and evaluation of a herbal sunscreen spray containing turmeric extract and Aloe vera for enhanced photoprotection and improved skin compatibility. The formulation was successfully prepared using a combination of herbal ingredients, moisturizing agents, antioxidants, and a physical UV filter. The obtained results demonstrated that the developed sunscreen spray possessed acceptable physicochemical properties, satisfactory stability, and promising photoprotective activity.

The organoleptic evaluation revealed that the formulation exhibited a smooth texture, pleasant odour, good homogeneity, and non-greasy consistency, which are important parameters for topical cosmetic acceptability. Spray formulations are increasingly preferred because they provide uniform application, ease of use, rapid drying, and improved consumer compliance compared to conventional creams and lotions. The oil-in-water emulsion system observed in the present formulation contributed to better spreadability and reduced stickiness on the skin surface.

The pH of the prepared formulation was found to be within the physiologically acceptable skin range, indicating good compatibility for topical application. Maintenance of appropriate pH is essential because highly acidic or alkaline formulations may cause irritation, dryness, or disruption of the skin barrier. No signs of redness, itching, or irritation were observed during the irritancy study, suggesting that the formulation was safe for topical use. Similar findings were reported by Ashawat et al. (2008), who stated that herbal topical formulations containing Aloe vera and plant-derived ingredients demonstrated improved skin compatibility and reduced irritation potential.

The prepared formulation also exhibited good spreadability and stability without visible phase separation during storage. Stability is an important factor in topical emulsions because instability may lead to changes in consistency, reduced efficacy, and poor consumer acceptability. The absence of rancidity indicated that oxidative degradation of oils did not occur significantly during the study period, possibly due to the antioxidant effect of vitamin E and turmeric constituents.

The SPF evaluation demonstrated that the prepared herbal sunscreen spray possessed appreciable photoprotective activity. The observed SPF value indicated effective absorption of UV radiation within the UVB region. Herbal constituents such as curcumin present in turmeric are known to possess antioxidant and UV-protective properties that contribute to photoprotection. Curcumin has been reported to reduce oxidative stress and inflammatory responses induced by ultraviolet radiation (F'guyer et al., 2003). Aloe vera also contributes to skin protection through moisturizing, soothing, and anti-inflammatory effects.

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

The antioxidant activity of herbal phytoconstituents plays a major role in minimizing UV-induced reactive oxygen species (ROS). Polyphenols and flavonoids present in plant extracts can neutralize free radicals generated during UV exposure and reduce photooxidative damage. Velasco et al. (2008) reported that bioactive phytoconstituents enhance broad-spectrum sunscreen activity while improving formulation safety and tolerability.

Zinc oxide incorporated in the formulation acted as a physical sunscreen agent by reflecting and scattering ultraviolet radiation. The combination of zinc oxide with herbal antioxidants may provide synergistic photoprotective activity. Compared to synthetic chemical sunscreens, herbal formulations may offer reduced risk of hypersensitivity reactions and improved environmental safety.

The comparative evaluation with marketed sunscreen preparations indicated that the herbal sunscreen spray possessed acceptable cosmetic characteristics and effective photoprotective potential. The presence of Aloe vera, glycerin, and coconut oil enhanced moisturizing properties and reduced greasiness, thereby improving overall consumer acceptability.

However, certain limitations remain associated with herbal sunscreen formulations. Variability in phytochemical composition, lower long-term stability, and lack of standardized extraction methods may influence formulation performance. Further studies involving advanced SPF analysis, microbial stability testing, accelerated stability studies, and in vivo clinical evaluation are required to validate the efficacy and commercial applicability of the formulation.



Overall, the results of the present study suggest that the formulated herbal sunscreen spray containing turmeric and Aloe vera can serve as a promising natural alternative to conventional synthetic sunscreens. The formulation demonstrated satisfactory physicochemical properties, stability, skin compatibility, and effective photoprotective activity, supporting its potential application in herbal cosmetic and dermatological preparations.

IX. CONCLUSION

The present study successfully formulated and evaluated a herbal sunscreen spray containing turmeric extract and Aloe vera for enhanced photoprotective activity and improved skin compatibility. The prepared formulation demonstrated satisfactory physicochemical characteristics including good homogeneity, smooth texture, acceptable pH, suitable spreadability, and stable emulsion properties. The formulation also showed no signs of irritation or rancidity, indicating its safety and stability for topical application.

The SPF evaluation confirmed that the herbal sunscreen spray possessed effective ultraviolet protective activity against harmful UV radiation. The presence of turmeric extract rich in curcumin, along with Aloe vera and zinc oxide, contributed significantly to antioxidant activity, skin soothing effects, and photoprotection. The incorporation of natural ingredients improved the cosmetic acceptability of the formulation while reducing the possibility of adverse effects commonly associated with synthetic sunscreen agents.

The results of the study suggest that the developed herbal sunscreen spray can serve as a promising natural alternative to conventional sunscreen formulations. The combination of herbal antioxidants, moisturizing agents, and physical UV filters provided effective protection against UV-induced skin damage while maintaining skin compatibility and user convenience. Thus, the formulation has potential applications in herbal cosmetics and dermatological preparations aimed at safer and eco-friendly sun protection.

X. FUTURE SCOPE

The present study provides a foundation for further research and development of herbal sunscreen formulations. Future investigations can focus on improving formulation efficacy, stability, and commercial applicability through advanced pharmaceutical approaches.

Advanced SPF Enhancement

Further studies can be carried out to improve the SPF value of the herbal sunscreen spray by incorporating additional natural UV-protective agents such as green tea extract, licorice extract, carrot seed oil, and raspberry seed oil. Optimization of herbal extract concentration and combination of synergistic phytoconstituents may enhance broad-spectrum photoprotective activity.

Nanoherbal Sunscreen Systems

Development of nanoherbal sunscreen formulations using nanotechnology-based carriers such as nanoemulsions, liposomes, solid lipid nanoparticles, and nanostructured lipid carriers may improve stability, skin penetration, bioavailability, and sustained release of herbal active constituents. Nanoformulations may also enhance SPF efficiency and improve formulation elegance.

Clinical Evaluation Studies

Further clinical studies involving human volunteers are required to evaluate long-term safety, efficacy, skin compatibility, and dermatological acceptance of the herbal sunscreen spray. Clinical investigations can help establish standardized dosage recommendations and validate the formulation for commercial application.

Broad Spectrum UV Testing

Additional studies should be conducted to evaluate broad-spectrum UVA and UVB protection using advanced analytical techniques and in vivo testing methods. Photostability studies and standardized international SPF evaluation protocols can further strengthen the scientific reliability and regulatory acceptance of the formulation.



Additional Future Perspectives

- Development of preservative-free herbal sunscreen formulations.
- Evaluation of antimicrobial and anti-aging properties of the formulation.
- Incorporation of natural fragrance and cooling agents for improved consumer acceptability.
- Large-scale manufacturing and commercialization studies.
- Assessment of environmental safety and biodegradability of herbal sunscreen ingredients.

REFERENCES

- [1]. American Academy of Dermatology. (n.d.). *How to apply sunscreen*. Retrieved from American Academy of Dermatology – How to apply sunscreen
- [2]. Ashawat, M. S., Saraf, S., & Saraf, S. (2008). Preparation and characterization of herbal creams for improvement of skin viscoelastic properties. *International Journal of Cosmetic Science*, 30(3), 183–193. Wiley Online Library – Herbal Cream Study
- [3]. Baby, A. R., Maciel, C. P. M., Kaneko, T. M., & Velasco, M. V. R. (2006). UV spectrophotometric determination of bioflavonoids from pharmaceutical dosage forms. *Journal of AOAC International*, 89(6), 1532–1537. Journal of AOAC International – Bioflavonoids Study
- [4]. Centers for Disease Control and Prevention. (2025). *Ultraviolet Radiation*. Retrieved from CDC – Ultraviolet Radiation
- [5]. F'guyer, S., Afaq, F., & Mukhtar, H. (2003). Photochemoprevention of skin cancer by botanical agents. *Photodermatology, Photoimmunology & Photomedicine*, 19(2), 56–72. Wiley Online Library – Botanical Agents and Skin Cancer
- [6]. Movileanu, L., Neagoe, I., & Flonta, M. L. (2000). Interaction of the antioxidant flavonoid quercetin with planar lipid bilayers. *International Journal of Pharmaceutics*, 205(1–2), 135–146. ScienceDirect – Flavonoid Antioxidant Study
- [7]. Rashid, S. A., Sharma, S., Mohanlal, V., & Ravichandran, V. (2012). Formulation, characterization and in vitro evaluation of herbal sunscreen lotion. *International Journal of Pharmaceutical Sciences Review and Research*, 16(2), 57–63. IJPSRR – Herbal Sunscreen Lotion Study
- [8]. Sonawane, S., Pujari, K., Kulkarni, S. S., & Kulkarni, S. D. (2021). Formulation and evaluation of herbal sunscreen cream. *International Journal of Creative Research Thoughts*, 9(1), 2320–2882. IJCRT – Herbal Sunscreen Cream Study
- [9]. Tabrizi, H., Mortazavi, S. A., & Kamalinejad, M. (2003). An in vitro evaluation of various Rosa damascena flower extracts as a natural antisolar agent. *International Journal of Cosmetic Science*, 25(6), 259–265. Wiley Online Library – Natural Antisolar Agent Study
- [10]. Velasco, M. V. R., Sarruf, F. D., Salgado-Santos, I. M. N., Haroutiounian-Filho, C. A., Kaneko, T. M., & Baby, A. R. (2008). Broad spectrum bioactive sunscreens. *International Journal of Pharmaceutics*, 363(1–2), 50–57. ScienceDirect – Broad Spectrum Bioactive Sunscreens
- [11]. World Health Organization. (2022). *Ultraviolet radiation fact sheet*. Retrieved from WHO – Ultraviolet Radiation Fact Sheet
- [12]. World Health Organization. (n.d.). *Radiation: Protecting against skin cancer*. Retrieved from WHO – Protecting Against Skin Cancer
- [13]. World Health Organization. (n.d.). *Radiation: Ultraviolet (UV) radiation*. Retrieved from WHO – UV Radiation Q&A
- [14]. World Health Organization. (n.d.). *Ultraviolet radiation*. Retrieved from WHO – Ultraviolet Radiation Overview

