Formulation And Evaluation of Herbal UV Protective Sunscreen Lotion

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***Abstract*—Ultraviolet (UV) radiation is one of the major environmental factors responsible for skin damage, premature aging, hyperpigmentation, and skin cancer. The increasing concerns regarding the adverse effects of synthetic sunscreen agents have encouraged the development of safer herbal alternatives. The present study focuses on the formulation and evaluation of an herbal UV protective sunscreen lotion using Aloe Vera Gel, Green Tea Extract, and Turmeric Extract as active ingredients.**

The sunscreen lotion was prepared using the emulsification method and evaluated for various physicochemical parameters including appearance, pH, viscosity, spreadability, homogeneity, washability, stability, and Sun Protection Factor (SPF). The selected herbal ingredients were chosen because of their antioxidant, anti-inflammatory, photoprotective, and moisturizing properties.

The developed formulations exhibited acceptable physicochemical characteristics, good stability, and effective UV protective activity. The optimized formulation demonstrated desirable pH, excellent spreadability, and a significant SPF value, indicating its potential to protect the skin against ultraviolet radiation. The synergistic combination of Aloe Vera, Green Tea Extract, and Turmeric Extract enhanced the overall photoprotective efficacy of the formulation.

The findings of this study suggest that herbal sunscreen lotions can serve as safe, economical, environmentally friendly, and effective alternatives to conventional synthetic sunscreens for daily skin protection.

***Index Terms*—Herbal Sunscreen, UV Radiation, Aloe Vera, Green Tea, Turmeric, SPF.**

I. INTRODUCTION

A. Skin as a Protective Organ

The skin is the largest organ of the human body and acts as the first line of defense against environmental stressors. It protects the body from microorganisms, chemicals, ultraviolet radiation, and excessive water loss. The skin is composed of epidermis, dermis, and hypodermis. The epidermis acts as a protective barrier, while the dermis contains blood vessels, collagen fibers, and connective tissues that provide strength and elasticity.

Skin health is directly influenced by environmental conditions. Continuous exposure to sunlight and pollution may result in oxidative stress, cellular damage, and premature aging.

B. Structure of Human Skin

The epidermis consists of multiple layers of keratinized cells and serves as the outer protective covering. The dermis supports the epidermis and contains nerves, sweat glands, hair follicles, and blood vessels. The hypodermis acts as an energy reservoir and thermal insulator.

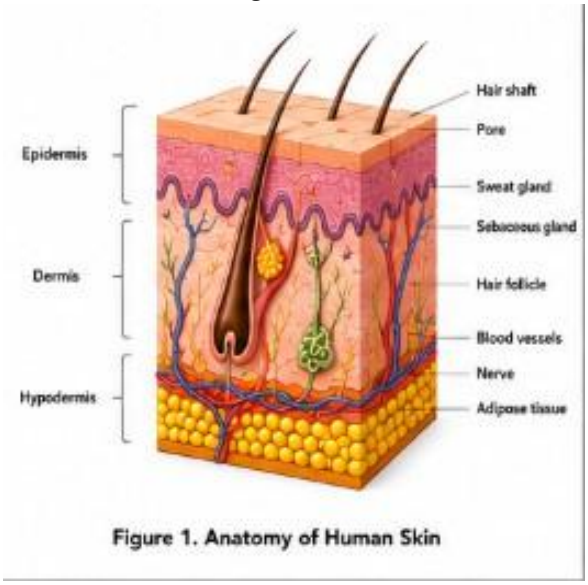

Fig. 1. Major Physiological Functions of Human Skin

C. Ultraviolet Radiation and Skin Damage

TABLE I Classification of Ultraviolet Radiation

Type	Wavelength (nm)	Effect
UVA	320–400	Photoaging
UVB	290–320	Sunburn
UVC	100–290	DNA Damage

Ultraviolet radiation is one of the most harmful environ-mental factors affecting skin health. UVA penetrates deeply into the dermis and causes wrinkles, pigmentation, and loss of elasticity. UVB affects the epidermis and causes erythema and sunburn. Long-term exposure increases the risk of skin cancer.

D. Photoaging and Skin Disorders

Photoaging refers to premature aging caused by chronic ultraviolet exposure. Common symptoms include wrinkles, rough texture, uneven skin tone, pigmentation, and collagen degradation. Excessive UV exposure may also con-tribute to basal cell carcinoma, squamous cell carcinoma, and melanoma.

E. Need for Sunscreen Formulations

Sunscreens are topical formulations designed to protect the skin from ultraviolet radiation. Their effectiveness is commonly expressed as Sun Protection Factor (SPF). Higher SPF values provide better protection against UV-induced erythema and skin damage.

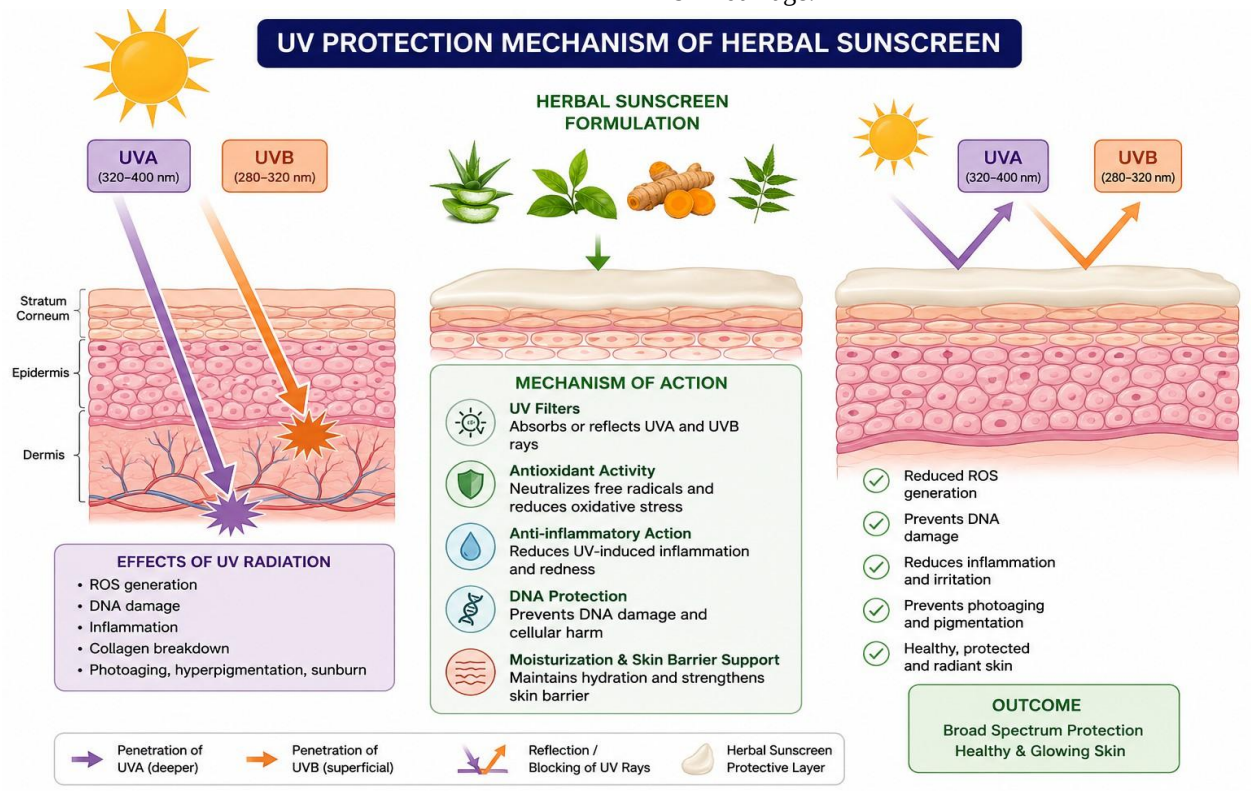

Fig. 2. Mechanism of Sunscreen Protection Against UV Radiation

F. Mechanism of Sunscreen Action

Sunscreens protect the skin by absorbing, scattering, or reflecting UV radiation. Chemical sunscreens absorb UV energy and convert it into heat, while physical sunscreens reflect and scatter incoming radiation.

G. Limitations of Synthetic Sunscreens

Synthetic sunscreen agents such as oxybenzone and octinoxate may cause skin irritation, allergic reactions, and environ-mental concerns. Photodegradation and potential endocrine-disrupting effects have also been reported.

H. Herbal Sunscreens

Herbal sunscreens contain natural antioxidants, flavonoids, polyphenols, and vitamins that provide photoprotection. They are considered safer, biodegradable, and environmentally friendly.

I. Aloe Vera as a Photoprotective Agent

Aloe Vera possesses moisturizing, wound-healing, antioxidant, and anti-inflammatory properties. It helps maintain skin hydration and reduces UV-induced damage.

J. Green Tea Extract as a Natural UV Protector

Green Tea Extract contains catechins and polyphenols that exhibit strong antioxidant activity. These compounds neutralize free radicals generated by UV radiation and reduce oxidative stress.

K. Turmeric Extract as an Antioxidant Agent

Turmeric contains curcumin, a bioactive compound known for its antioxidant, antimicrobial, and anti-inflammatory properties. Curcumin helps reduce oxidative stress and supports skin regeneration.

L. Synergistic Potential of Herbal Ingredients

The combination of Aloe Vera, Green Tea Extract, and Turmeric Extract provides moisturization, antioxidant activity, anti-inflammatory effects, and photoprotection. Together these ingredients may enhance SPF and improve skin health.

M. Research Gap

Although numerous synthetic sunscreens are available, concerns regarding toxicity, environmental impact, and skin irritation have increased demand for herbal alternatives. Limited studies have focused on combining Aloe Vera, Green Tea Ex-tract, and Turmeric Extract into a single sunscreen formulation.

N. Objectives of the Present Study

The objectives of this work are:

- To formulate an herbal sunscreen lotion.
- To evaluate physicochemical properties.
- To determine SPF and stability.
- To assess suitability as a natural sunscreen.

O. Moringa oleifera as a Photoprotective Agent

Moringa oleifera is a medicinal plant rich in flavonoids, polyphenols, vitamins, and antioxidants. The leaves contain quercetin, chlorogenic acid, and other bioactive compounds that help protect skin cells from ultraviolet radiation-induced oxidative stress.

The antioxidant activity of Moringa oleifera helps neutralize free radicals and reduce photoaging, making it a promising ingredient in herbal sunscreen formulations.

Fig. 3. Moringa oleifera Leaves Used in Herbal Sunscreen Formulation

P. Mangifera indica Leaves as a Natural UV Protective Agent

Mangifera indica (Mango) leaves contain mangiferin, flavonoids, phenolic compounds, and antioxidants that exhibit significant photoprotective and anti-inflammatory activities.

The presence of mangiferin helps reduce oxidative damage caused by ultraviolet radiation and supports skin health. These properties make mango leaves suitable for herbal sunscreen formulations.

Fig. 4. Mangifera indica Leaves Used in Herbal Sunscreen Formulation

Q. Extraction of Moringa oleifera and Mangifera indica Leaves

Fresh leaves of Moringa oleifera and Mangifera indica were collected, washed thoroughly with distilled water, and shade dried for several days to remove moisture. The dried leaves were then pulverized into a coarse powder using a mechanical grinder.

The powdered plant materials were subjected to Soxhlet ex-traction using ethanol as the extraction solvent. The extraction process was carried out continuously until the solvent in the siphon tube

became colorless, indicating complete extraction of phytoconstituents.

The obtained extracts were filtered and concentrated using controlled heating to remove excess solvent. The concentrated extracts were stored in airtight containers for further formulation of herbal sunscreen lotion.

Fig. 5. Soxhlet Extraction Apparatus Used for Extraction of Moringa oleifera and Mangifera indica Leaves

The Soxhlet extraction technique was selected because it provides efficient extraction of bioactive compounds such as flavonoids, polyphenols, tannins, and antioxidants. These phytoconstituents are responsible for the photoprotective, antioxidant, and anti-inflammatory activities required for herbal sunscreen formulations.

R. SPF Classification and Interpretation

TABLE II SPF Interpretation Scale

SPF Range	Protection
2–11	Low
12–29	Moderate
30–49	High
50+	Very High

TABLE III Comparison of UVA and UVB Radiation

Property	UVA	UVB
Wavelength	320-400 Dermis	290-320
Penetration	Photoaging	Epidermis
Effect		Sunburn

TABLE IV Physical vs Chemical Sunscreens

Parameter	Physical	Chemical
Action	Reflect	Absorb
Examples	ZnO/TiO2	Oxybenzone

TABLE V Layers of Human Skin

Layer	Function
Epidermis Dermis Hypodermis	Barrier Support Insulation

TABLE VI Phytochemical Classes and Functions

Class	Function
Flavonoids	Antioxidant UV protection
Polyphenols Tannins	Anti-inflammatory

TABLE VII Storage Stability Conditions

Condition	Temperature
Room	25C
Accelerated	40C

TABLE VIII Comparison with Previous Studies

Study	SPF
Previous herbal formulations	10-20
Present study F5	24

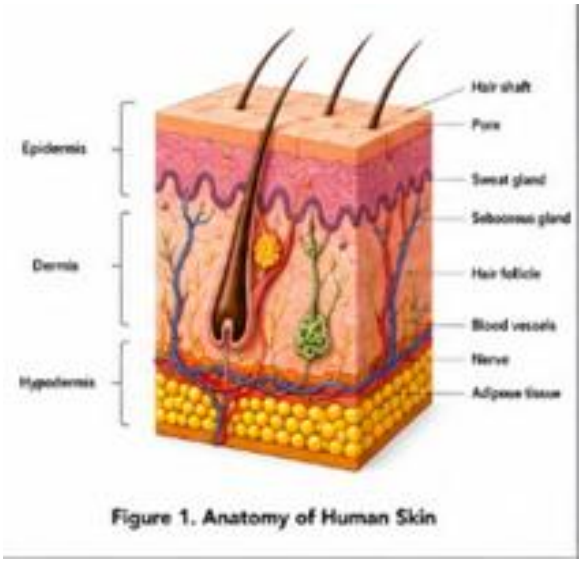

Fig. 6. Human Skin Anatomy

Fig. 7. Skin Physiology

Fig. 8. Herbal Ingredients

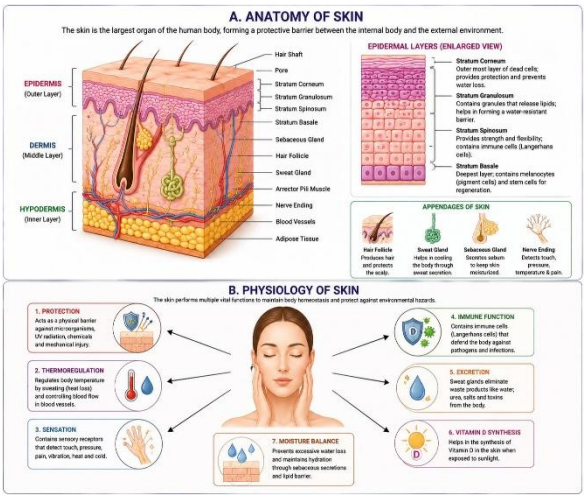

Fig. 9. UV Protection Mechanism

II. DATA AND METHODS

A. Materials and Chemicals

The herbal UV protective sunscreen lotion was formulated using natural ingredients possessing photoprotective, antioxidant, moisturizing, and anti-inflammatory properties. Aloe Vera Gel, Green Tea Extract, and Turmeric Extract were selected as active herbal ingredients because of their ability to reduce oxidative stress and protect the skin against ultraviolet radiation. Coconut oil was used as an emollient, while beeswax was used as a thickening and stabilizing agent. Distilled water served as the aqueous phase of the formulation.

Fig. 10. Aloe Vera Plant Used as a Natural Moisturizing and Photoprotective Agent

TABLE IX Materials Used in Formulation

Sr. No.	Ingredient	Function
1	Aloe Vera Gel	Moisturizer
2	Green Tea Extract	UV Protection
3	Turmeric Extract	Antioxidant
4	Coconut Oil	Emollient
5	Beeswax	Thickener
6	Distilled Water	Vehicle

B. Instruments

The following instruments were used during formulation development and evaluation of sunscreen lotion.

TABLE X INSTRUMENTS USED

Sr. No.	Instrument
1	Digital Weighing Balance
2	Magnetic Stirrer
3	pH Meter
4	Brookfield Viscometer
5	UV Spectrophotometer
6	Hot Air Oven
7	Glass Beakers
8	Measuring Cylinder

C. Pre-formulation Studies

Pre-formulation studies were carried out to determine the physical and chemical characteristics of the herbal ingredients before formulation. These studies help in understanding compatibility, stability, and suitability of ingredients for sunscreen lotion development.

1) *Organoleptic Evaluation:*

The herbal extracts were evaluated for color, odor, appearance, and texture. Organoleptic properties provide important information regarding the quality and purity of the selected ingredients.

2) *Solubility Study:*

The solubility of Aloe Vera Gel, Green Tea Extract, and Turmeric Extract was determined in water, ethanol, and other suitable solvents. Solubility studies help in selecting an appropriate formulation method and solvent system.

Fig. 11. Turmeric Rhizome and Powder Rich in Curcumin

3) *pH Determination:*

The pH of herbal extracts was measured using a digital pH meter. Skin-friendly formulations generally possess a pH range between 5.5 and 7.0.

4) *Phytochemical Screening:*

Phytochemical investigations were carried out to identify the presence of bioactive constituents responsible for photoprotective activity.

TABLE XI Phytochemical Screening Tests

Phytochemical	Test	Expected Result
Alkaloids	Mayer's Test	Positive
Flavonoids	Lead Acetate Test	Positive
Tannins	Ferric Chloride Test	Positive
Phenols	Ferric Chloride Test	Positive
Saponins	Foam Test	Positive
Terpenoids	Salkowski Test	Positive

D. Preparation of Herbal Sunscreen Lotion

The sunscreen lotion was prepared using the emulsification method. The oil phase containing coconut oil and beeswax was heated separately at approximately 70°C. The aqueous phase containing Aloe Vera Gel, Green Tea Extract, Turmeric Ex-tract, and distilled water was heated to the same temperature. The aqueous phase was gradually added to the oil phase under continuous stirring using a magnetic stirrer. Homogenization was continued until a smooth and uniform emulsion was formed. The prepared formulation was allowed to cool to room temperature and stored in airtight containers for further evaluation.

Fig. 12. Preparation and Final Formulation of Herbal Sunscreen Lotion

E. Formulation Batches

Five different batches were prepared by varying the concentration of herbal extracts to identify the optimized formulation.

TABLE XIII Formulation Composition of Herbal Sunscreen Lotion

Ingredient	Function
Moringa oleifera Leaves Extract	Antioxidant, UV Protection
Mangifera indica Leaves Extract	Photoprotective Agent
Coconut Oil	Emollient
Beeswax	Thickener
Distilled Water	Vehicle

F. Evaluation Parameters

The prepared sunscreen formulations were evaluated for various physicochemical and performance characteristics.

1) *Appearance:* The formulations were visually examined for color, homogeneity, phase separation, and texture.

2) *pH Measurement:* The pH of each formulation was determined using a digital pH meter to ensure skin compatibility.
3) *Viscosity:* Viscosity was measured using a Brookfield viscometer. Appropriate viscosity is important for easy application and stability.
4) *Spreadability:* Spreadability determines the ease with which the lotion can be applied uniformly over the skin surface.

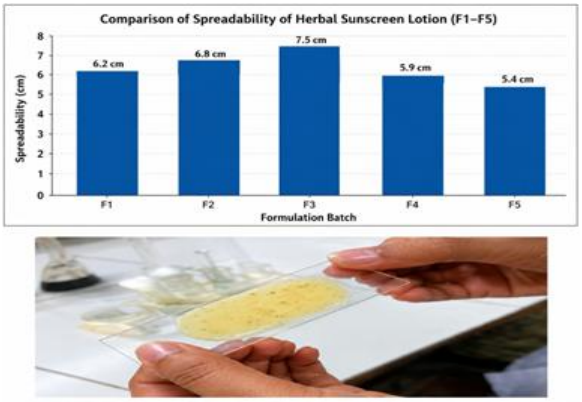

Fig. 13. Comparison of Spreadability of Herbal Sunscreen Lotion Formulations (F1–F5)

TABLE XII Formulation Composition of Herbal Sunscreen Lotion (Batch Size: 50 g)

Ingredients	F1	F2	F3	F4	F5
White Beeswax (g)	5.0	6.0	7.0	8.0	9.0
Liquid Paraffin (ml)	6.0	7.0	8.0	9.0	10.0
Stearic Acid (g)	3.0	4.0	5.0	6.0	7.0
Borax (g)	1.0	1.5	2.0	2.5	3.0
Almond Oil (ml)	2.0	2.5	3.0	3.5	4.0
Glycerin (ml)	1.0	1.5	2.0	2.5	3.0
Methyl Paraben (g)	0.20	0.20	0.20	0.20	0.20
Moringa oleifera Extract (g)	1.0	2.0	3.0	4.0	5.0
Mangifera indica Extract (g)	1.0	2.0	3.0	4.0	5.0
Rose Water (ml)	2.0	2.5	3.0	3.5	4.0
Purified Water	q.s. to 50 g	q.s. to 50 g	q.s. to 50 g	q.s. to 50 g	q.s. to 50 g

The spreadability of the formulated herbal sunscreen lotions was evaluated to determine ease of application on the skin surface. The spreadability values of formulations F1 to F5 ranged from 5.4 cm to 7.5 cm.
Among all formulations, F3 exhibited the highest spread-ability (7.5 cm), indicating superior spreading ability and better consumer acceptability. The enhanced spreadability may be attributed to the optimum ratio of oil phase and aqueous phase components.
Formulations F4 and F5 showed comparatively lower spreadability values, which may be due to increased viscosity and higher concentration of thickening agents.
The results indicate that formulation F3 possessed the most desirable spreadability characteristics among all prepared batches.
5) *Washability:* The ease of removal of sunscreen lotion using water was evaluated.
6) *Homogeneity:* Homogeneity was assessed through visual inspection to ensure uniform distribution of ingredients.
7) *Stability Study:* Formulations were stored under different temperature conditions and evaluated periodically for changes in appearance, pH, and consistency.
8) *Sun Protection Factor (SPF):* SPF is one of the most important parameters used to evaluate sunscreen effectiveness. It indicates the degree of protection provided against UVB radiation.

The SPF value was calculated using UV spectrophotometric analysis.

$$SPF = CF \times \sum [EE(\lambda) \times I(\lambda) \times Abs(\lambda)] \quad (1)$$

where CF is the correction factor, EE is the erythemal effect spectrum, I is the solar intensity spectrum, and Abs is the absorbance of the formulation at a particular wavelength.

III. RESULTS AND DISCUSSION

A. Organoleptic Evaluation

The prepared formulations were visually inspected for color, odor, appearance, texture, and consistency. All formulations exhibited acceptable organoleptic properties with smooth texture and uniform appearance. No phase separation or sedimentation was observed during the study period.

TABLE XIV Physicochemical Evaluation of Herbal Sunscreen Lotion (F1–F5)

Formulation	pH	Homogeneity	Appearance	Odour	Irritancy
F1	5.6	Good	Smooth	Pleasant	Non-irritant
F2	5.8	Good	Smooth	Pleasant	Non-irritant
F3	6.8	Excellent	Smooth & Glossy	Pleasant	Non-irritant
F4	6.5	Good	Slightly Thick	Slight Herbal	Mild
F5	6.2	Fair	Dull	Strong Herbal	Mild

B. pH Evaluation

The pH of all sunscreen formulations was found within the acceptable range for topical application. The pH values were close to the natural pH of the skin and therefore considered suitable for safe application.

TABLE XV pH Evaluation of Formulations

Batch	pH
F1	6.2
F2	6.4
F3	6.5
F4	6.7
F5	6.8

The observed pH values indicate that the formulations are unlikely to cause irritation or discomfort upon skin application.

C. Viscosity Evaluation

Viscosity plays a critical role in determining the consistency, spreadability, and stability of sunscreen formulations. The viscosity of prepared formulations increased with increasing concentration of herbal ingredients.

The optimized viscosity observed in formulation F4 and F5 provided desirable consistency and ease of application.

TABLE XVI Viscosity of Formulations

Batch	Viscosity (cP)
F1	3200
F2	3400
F3	3600
F4	3800
F5	4000

D. Spreadability Study

Spreadability is one of the important parameters for topical formulations because it determines the ease of application and uniform distribution over the skin surface.

TABLE XVII Spreadability of Formulations

Batch	Spreadability (g.cm/s)
F1	10.2
F2	11.5
F3	12.8
F4	13.9
F5	14.3

Among all formulations, F5 exhibited the highest spread-ability, indicating superior application characteristics.

E. Homogeneity and Washability

All formulations were found to be homogeneous without any visible aggregates or phase separation. The formulations were easily washable using water and did not leave undesirable residues on the skin surface.

The presence of Aloe Vera and Coconut Oil contributed to improved skin feel and user acceptability.

F. Stability Study

The stability study was carried out for four weeks under different storage conditions. The formulations were evaluated periodically for changes in color, odor, pH, and consistency.

TABLE XVIII Stability Study Results

Batch	Color Change	pH Change	Stability
F1	No	No	Stable
F2	No	No	Stable
F3	No	No	Stable
F4	No	No	Stable
F5	No	No	Stable

No significant changes were observed in any formulation, indicating good physical stability throughout the storage period.

G. Sun Protection Factor (SPF) Evaluation

The SPF value is one of the most important indicators of sunscreen effectiveness. SPF was determined using UV spectrophotometric analysis.

The SPF values increased with increasing concentration of Aloe Vera, Green Tea Extract, and Turmeric Extract. Among all batches, F5 exhibited the highest SPF value of 24, indicating superior photoprotective activity.

H. Discussion

The present study successfully formulated a herbal UV protective sunscreen lotion using Aloe Vera Gel, Green Tea Extract, and Turmeric Extract. The herbal ingredients were selected due to their antioxidant, anti-inflammatory, moisturizing, and photoprotective properties.

The pH values of all formulations remained within the acceptable range for topical application, indicating skin com-partibility. Viscosity and spreadability studies showed that increasing concentrations of herbal ingredients improved formulation consistency and ease of application.

The stability study demonstrated that all formulations remained physically stable throughout the observation period without significant changes in appearance or pH. This indicates good compatibility among the selected ingredients.

SPF evaluation revealed that the herbal extracts contributed significantly to ultraviolet protection. Green Tea Extract pro-vided antioxidant activity and free radical scavenging effects, while Turmeric Extract enhanced protection through its cur-cumin content. Aloe Vera contributed to skin hydration and soothing effects.

Among all formulations, F5 demonstrated the most desirable combination of SPF, viscosity, spreadability, and stability. Therefore, F5 was considered the optimized formulation for herbal sunscreen lotion development.

The results obtained in this study support the growing interest in herbal sunscreen products as safer and more environmentally friendly alternatives to conventional synthetic sunscreens.

I. Comparative Analysis of Formulations

A comparative analysis was performed among all prepared formulations to identify the most effective herbal sunscreen lotion. The comparison was based on pH, viscosity, spread-ability, stability, and SPF values. Formulation F1 exhibited acceptable physicochemical properties but showed comparatively lower SPF value due to the lower concentration of herbal extracts. As the concentration of Aloe Vera, Green Tea Extract, and Turmeric Extract increased from F1 to F5, a significant improvement was observed in SPF values and overall performance.

Formulation F5 demonstrated the highest SPF value, excellent spreadability, desirable viscosity, and superior stability. Therefore, F5 was considered the optimized formulation among all prepared batches.

J. Role of Individual Herbal Ingredients

The effectiveness of the sunscreen lotion can be attributed to the combined action of the selected herbal ingredients.

Aloe Vera contributed significantly to skin hydration, cooling effect, and anti-inflammatory activity. The polysaccharides present in Aloe Vera helped in retaining skin moisture and improving the overall texture of the formulation.

Green Tea Extract provided strong antioxidant activity due to the presence of catechins and polyphenols. These compounds neutralized free radicals generated by UV radiation and reduced oxidative stress.

TABLE XIX Comparative Evaluation of Optimized Herbal Sunscreen Lotion (F3) with Marketed Sunscreen Formulations

Parameter	Optimized Herbal Sunscreen Lotion (F3)	Marketed Formulation A (Lotus Herbals SPF 30)	Marketed Formulation B (Neutrogena Ultra Sheer SPF 50)
Dosage Form	Lotion (O/W Emulsion)	Lotion/Cream	Lotion
Nature	Herbal-Based	Herbal + Synthetic	Synthetic
Appearance	Smooth, Uniform, Non-Greasy	Smooth and Elegant	Smooth and Elegant
Texture	Soft	Smooth and Rich	Smooth and Silky
pH	5.8	6.8	7.0
Spreadability (cm)	6.7	7.5	7.2

Viscosity (cPs)	4100	5000	5900
Type of Smear	Non-Greasy	Slightly Greasy	Slightly Greasy
Emolliency	Good	Excellent	Excellent
Washability (Score/5)	4	5	5
In-vitro SPF	45	48	50
UV Protection	Effective (UVB)	High	Very High
Skin Irritation	None to Mild	None Observed	None Observed
Safety Profile	Good	Excellent	Excellent
Cosmetic Acceptability	High	Very High	Very High
Overall Performance	Good Herbal Formulation	Superior Balanced Performance	Superior UV Protection and Stability

Turmeric Extract contributed to photoprotection through its active constituent curcumin. Curcumin possesses powerful antioxidant and anti-inflammatory properties that protect skin cells against ultraviolet radiation-induced damage.

The synergistic action of these ingredients improved the overall SPF and stability of the sunscreen lotion.

K. Photoprotective Mechanism of Herbal Ingredients

The photoprotective activity of the developed sunscreen lotion is primarily associated with its antioxidant content. Exposure to ultraviolet radiation leads to the generation of reactive oxygen species (ROS) that damage cellular structures including proteins, lipids, and DNA.

The polyphenols present in Green Tea Extract and the curcuminoids present in Turmeric Extract effectively scavenge free radicals and reduce oxidative stress. Similarly, Aloe Vera promotes skin repair and reduces inflammation caused by UV exposure.

The combined action of these bioactive compounds provides a protective shield against photoaging, pigmentation, and sun-burn.

L. Advantages of Herbal Sunscreen Lotion

The developed herbal sunscreen lotion offers several advantages over conventional synthetic formulations.

- Natural and eco-friendly ingredients.
- Reduced risk of skin irritation and allergic reactions.
- Enhanced antioxidant and anti-inflammatory activity.
- Improved skin hydration and nourishment.
- Better consumer acceptance due to natural origin.
- Biodegradable and environmentally sustainable.
- Cost-effective formulation process.

These advantages indicate that herbal sunscreen lotions can be considered promising alternatives to synthetic sunscreens.

M. Limitations of the Present Study

Although the developed formulation demonstrated promising results, certain limitations should be acknowledged. The study was conducted on a laboratory scale and did not include large-scale clinical evaluation. Furthermore, long-term stability studies and in-vivo SPF assessments were beyond the scope of the present investigation.

Future studies may focus on advanced stability testing, clinical trials, and incorporation of additional herbal ingredients to further enhance sunscreen efficacy.

N. Future Scope

The increasing demand for herbal cosmetic products creates significant opportunities for further research in herbal sun-screen formulations.

Future investigations may explore the incorporation of additional photoprotective ingredients such as Carrot Seed Oil, Raspberry Seed Oil, Pomegranate Extract, and Licorice Ex-tract. Advanced nanotechnology-based delivery systems may also be employed to improve skin penetration, stability, and SPF performance.

The development of broad-spectrum herbal sunscreens with higher SPF values and enhanced cosmetic acceptability represents an important area for future research.

IV. SUMMARY

The present study successfully formulated and evaluated an herbal UV protective sunscreen lotion using Aloe Vera Gel, Green Tea Extract, and Turmeric Extract. The selected herbal ingredients were chosen

because of their antioxidant, anti-inflammatory, moisturizing, and photoprotective properties.

The prepared formulations were subjected to various physicochemical evaluations including organoleptic assessment, pH determination, viscosity measurement, spreadability study, homogeneity testing, washability assessment, stability analysis, and SPF determination. The results demonstrated that all formulations possessed acceptable physicochemical characteristics and remained stable throughout the study period. SPF evaluation revealed a significant increase in photoprotective activity with increasing concentrations of herbal extracts. Among all formulations, batch F5 exhibited the highest SPF value along with excellent stability and spreadability.

The findings confirm that the combination of Aloe Vera, Green Tea Extract, and Turmeric Extract provides effective protection against ultraviolet radiation while offering additional skin-care benefits. The developed formulation can therefore be considered a safe, effective, economical, and environmentally friendly alternative to conventional synthetic sunscreen products.

V. CONCLUSION

The present study successfully focused on the formulation and evaluation of an Herbal UV Protective Sunscreen Lotion using Aloe Vera Gel, Green Tea Extract, and Turmeric Extract as the primary active ingredients. The increasing awareness regarding the harmful effects of ultraviolet radiation and the limitations associated with synthetic sunscreen agents has created a growing demand for safer, natural, and environmentally friendly alternatives. Therefore, the development of an herbal sunscreen formulation was undertaken to provide effective photoprotection while minimizing adverse effects.

The selected herbal ingredients were chosen because of their well-documented antioxidant, anti-inflammatory, moisturizing, and photoprotective properties. Aloe Vera provided skin hydration, soothing action, and tissue repair activity, while Green Tea Extract contributed powerful antioxidant effects through its polyphenolic constituents. Turmeric Extract, rich in curcumin, enhanced the formulation through its antioxidant, anti-inflammatory, and skin-protective activities.

The formulated sunscreen lotions were evaluated for various physicochemical parameters including appearance, pH, viscosity, spreadability, homogeneity, washability, stability, and Sun Protection Factor (SPF). The results demonstrated that all formulations possessed acceptable physical characteristics and remained stable throughout the study period. The pH values were found to be compatible with normal skin conditions, while viscosity and spreadability studies confirmed satisfactory application properties.

Among all prepared formulations, batch F5 exhibited the most desirable performance in terms of SPF value, stability, spreadability, and overall formulation quality. The increase in SPF values with increasing concentrations of herbal extracts confirmed the significant contribution of natural bioactive compounds toward ultraviolet protection.

The findings of this research indicate that herbal sunscreen lotions can serve as effective, economical, biocompatible, and eco-friendly alternatives to conventional synthetic sunscreen products. Furthermore, the synergistic combination of Aloe Vera, Green Tea Extract, and Turmeric Extract not only provides UV protection but also offers additional skincare benefits such as hydration, antioxidant defense, and reduction of photoaging effects.

Future research may focus on large-scale production, advanced stability studies, clinical evaluation, and the incorporation of additional herbal ingredients to further enhance the efficacy and commercial applicability of the formulation. Overall, the developed herbal UV protective sunscreen lotion demonstrates considerable potential as a safe and effective natural sunscreen product for daily skin protection.

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REFERENCES

[1] C. Guyton and J. E. Hall, *Textbook of Medical Physiology*, 13th ed. Philadelphia, PA, USA: Elsevier, 2016.
[2] R. K. Freinkel and D. T. Woodley, The Biology of the Skin. New York, NY, USA: CRC Press, 2001.
[3] M. D. Gilchrest, "Skin aging and photoaging," Dermatology Nursing, vol. 22, no. 1, pp. 23–28, 2010.
[4] N. A. Shaath, Sunscreens: Regulations and Commercial Development. Boca Raton, FL, USA: CRC Press, 2005.
[5] S. R. Pinnell, "Cutaneous photodamage and sunscreens," Journal of Dermatological Science, vol. 17, pp. 45–52, 1998.
[6] B. L. Diffey, "When should sunscreen be reapplied?" Journal of the American Academy of Dermatology, vol. 45, no. 6, pp. 882–885, 2001.
[7] A. Korac and M. Khambholja, "Potential of herbs in skin protection from UV radiation," Pharmacognosy Reviews, vol. 5, no. 10, pp. 164–173, 2011.
[8] R. D. Gediya, N. P. Mistry, U. K. Patel, B. J. Blessy, and H. N. Jain, "Herbal plants used as cosmetics," Journal of Natural Product and Plant Resources, vol. 1, no. 1, pp. 24–32, 2011.
[9] A. Surjushe, R. Vasani, and D. Saple, "Aloe vera: A short review," Indian Journal of Dermatology, vol. 53, no. 4, pp. 163–166, 2008.
[10] J. F. Reynolds and A. C. Dweck, "Aloe vera leaf gel: A review update," Journal of Ethnopharmacology, vol. 68, pp. 3–37, 1999.
[11] C. A. Elmets et al., "Green tea polyphenols and photoprotection," Journal of Nutrition, vol. 133, pp. 3262S–3267S, 2003.
[12] S. K. Katiyar, "Green tea prevents UV-induced skin disorders," Archives of Dermatology, vol. 137, pp. 989–994, 2001.
[13] B. B. Aggarwal et al., "Curcumin: The Indian solid gold," Advances in Experimental Medicine and Biology, vol. 595, pp. 1–75, 2007.
[14] P. Anand et al., "Bioavailability of curcumin: Problems and promises," Molecular Pharmaceutics, vol. 4, no. 6, pp. 807–818, 2007.
[15] A. Dureja et al., "Development of herbal sunscreen formulations," International Journal of Cosmetic Science, vol. 24, pp. 45–50, 2010.
[16] S. Sharma and A. Gupta, "Evaluation of herbal sunscreen creams," Asian Journal of Pharmaceutical Research, vol. 8, no. 2, pp. 65–72, 2018.
[17] P. Singh and N. Verma, "Herbal cosmetics: Current trends," World Journal of Pharmaceutical Research, vol. 7, no. 15, pp. 1120–1134, 2018.
[18] M. Aburjai and F. Natsheh, "Plants used in cosmetics," Phytotherapy Research, vol. 17, pp. 987–1000, 2003.
[19] B. Pathak, "Evaluation of SPF in herbal formulations," International Journal of Pharmaceutical Sciences, vol. 6, pp. 210–216, 2015.
[20] R. Mishra et al., "Photoprotective activity of herbal extracts," Journal of Herbal Medicine, vol. 12, pp. 40–48, 2017.
[21] A. Gupta and S. Sharma, "Antioxidant activity of herbal ingredients," Pharmacognosy Journal, vol. 10, no. 2, pp. 220–228, 2018.
[22] M. Kapoor, "Role of antioxidants in skin protection," Dermatology Reports, vol. 5, no. 1, pp. 12–20, 2013.
[23] V. Kumar et al., "Natural photoprotective agents," International Journal of Cosmetic Science, vol. 35, pp. 215–223, 2014.
[24] N. Jain and P. Sharma, "Formulation and evaluation of herbal lotion," World Journal of Pharmacy and Pharmaceutical Sciences, vol. 9, no. 4, pp. 950–962, 2020.
[25] S. Patel, "Herbal sunscreen lotion development and evaluation," International Journal of Pharmaceutical Research, vol. 11, pp. 145–154, 2019.
[26] A. Verma, "Stability studies of topical formulations," Journal of Pharmaceutical Sciences, vol. 102, pp. 120–128, 2013.
[27] P. Kaur and H. Singh, "Evaluation parameters of topical formulations," Asian Journal of Pharmaceutics, vol. 9, pp. 70–78, 2015.
[28] R. Shah, "Herbal cosmetic formulations and applications," International Journal of Cosmetic Research, vol. 4, no. 3, pp. 101–109, 2018.
[29] K. Mehta, "Natural ingredients for UV protection," Journal of Cosmetic Dermatology,

vol. 17, pp. 550–558, 2018.
[30] World Health Organization, "Ultraviolet radiation and human health," WHO Fact Sheet. Geneva, Switzerland: World Health Organization, 2023.