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Anti-Herbal Skin Shield Gel: Development of a Multi-Functional Herbal Protective Formulation Against Environmental Stressors

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Abstract: ***Rapid urbanization and increasing environmental pollution have increased human skin exposure to particulate matter, ultraviolet (UV) radiation, high-energy visible (HEV/blue) light, and microbial contaminants. Conventional chemical-based skin shields often carry risks of toxicity, irritation, and are of ecological burden. This study presents the formulation and evaluation of the Anti-Herbal Skin Shield Gel, a multi-functional, plant-derived protective topical gel designed to form a breathable antioxidant barrier against the various insults on skin.***
The formulation incorporates synergistic herbal activesAloe vera, Neem (Azadirachta indica), Moringa oleifera, Green Tea (Camellia sinensis), Turmeric (Curcumin), Licorice (Glycyrrhiza glabra, Yashtimadhu), Tulsi (Ocimum sanctum), and natural Vitamin Ein a polysaccharide gel base formulation. Evaluation parameters for the gel included pH, viscosity, spreadability, antioxidant activity (DPPH free-radical scavenging), patch test irritation scoring, and accelerated stability testing. Prototype results demonstrated a clear, non-sticky gel with excellent spreadability, rapid absorption, no observable irritation, and significant reduction in skin dullness and dryness. These findings support the feasibility of an all-natural skin shield as a safer, sustainable alternative to synthetic skin protection products.
Keywords: herbal gel, skin shield, antioxidant, UV protection, natural cosmeceutical

I. INTRODUCTION

The skin is the body's largest organ and functions as the first line of defense against various external environmental factors with a negative impact on skin [1]. The accelerating pace of urbanization has increasedexposure to environmental pollutantsincluding particulate matter (PM2.5, PM10), ground-level ozone, nitrogen oxides, and polycyclic aromatic hydrocarbonsalongside ultraviolet radiation [2][3]. Collectively, these stressors induce oxidative stress, disrupt the skin microbiome, accelerate photoaging, and compromise the epidermal barrier [4].

In response to these, global cosmeceutical market has responded with synthetic skin shield formulations; however, consumer and regulatory concern over synthetic preservatives, UV filters (e.g., oxybenzone), and synthetic antioxidants have fueled demand for natural, plant-derived alternatives [6]. Medicinal plants contain many potent phytochemicals like polyphenols, flavonoids, terpenoids, and polysaccharides that possess proven antioxidants, anti-inflammatory, photoprotective, and antimicrobial activities. These natural chemicals can be the substitute to the aggressive chemicals used in conventional synthetic formulations [7][8].

Aloe vera is known for its moisturizing, wound-healing, and anti-inflammatory effects due to its polysaccharides and anthraquinones [9]. Neem offers antimicrobial and anti-inflammatory activity via azadirachtin, while Moringa oleifera delivers antioxidant and UV-protective benefits through isothiocyanates and quercetin glycosides [10]. Green tea contains polyphenols, particularly EGCG, exhibit strong antioxidant, photoprotective, and anti-carcinogenic effects [11]. Curcumin from Curcuma longa reduces inflammation by modulating NF-κB pathways [12]. Glycyrrhiza glabra (licorice) provides skin-brightening and anti-inflammatory benefits, and Ocimum sanctum (Tulsi) supports antioxidant and antimicrobial defense [13][14]. Natural vitamin E (α-tocopherol) enhances antioxidant activity and stabilizes the skin's lipid barrier and provide moisturizing effects [15].

The present study was done to formulate and evaluate an anti-herbal skin shield gel that utilizes the synergistic effects of carefully selected herbal bioactives within a biocompatible gel matrix to provide multi-functional protection against environmental aggressors such as pollution, UV damage as well as microbial damage. Additionally, the formulation is designed to support skin repair, enhance barrier integrity, and promote overall skin health through natural, plant-derived ingredients.

II. MATERIALS AND METHODS

A. Herbal Raw Materials

The following herbal actives were sourced from certified suppliers and authenticated at the departmental herbarium: Aloe vera gel (fresh and standardized extract), Neem leaf extract, Moringa leaf extract, Green Tea extract (standardized to ≥98% polyphenols), Turmeric extract (curcumin ≥95%), Licorice root extract (glabridin ≥40%), Tulsi leaf extract, and natural Vitamin E (d-α-tocopherol ≥98%). All materials conformed to pharmacopoeial standards.

S. No.	Ingredient	Source/Form	Function
1	Aloe vera	Fresh gel & extract	Moisturizing, wound-healing, anti-inflammatory
2	Neem (*Azadirachta indica*)	Leaf extract	Antimicrobial, anti-inflammatory
3	Moringa (*Moringa oleifera*)	Leaf extract	Antioxidant, UV protection
4	Green Tea (*Camellia sinensis*)	Extract	Antioxidant, photoprotective
5	Turmeric (*Curcuma longa*)	Extract	Anti-inflammatory, antioxidant
6	Licorice (*Glycyrrhiza glabra*)	Root extract	Skin-brightening, anti-inflammatory
7	Tulsi (*Ocimum sanctum*)	Leaf extract	Antioxidant, antimicrobial
8	Vitamin E	Natural (d-α-tocopherol)	Antioxidant, stabilizer
9	Carbopol 940	1% w/w in purified water	Gelling agent
10	Glycerin	10% w/v	Humectant

B. Gel Base Preparation

A Carbopol 940-based gel base was prepared by dispersing 1% w/w Carbopol 940 in purified water under slow stirring. Glycerin (10% w/v) was incorporated as a humectant. The base was neutralized to pH 6.0 using triethanolamine and allowed to hydrate for 24 hours. The gel was sterilized by autoclaving at 121°C for 15 minutes prior to herbal incorporation.

C. Formulation Protocol

Herbal extracts were incorporated into the gel base in a stepwise manner under magnetic stirring (500 rpm, 25°C) to minimize thermal degradation of thermolabile constituents. The processing workflow was as follows:

1) Herbal Selection and standardization
2) Extraction (maceration and percolation as appropriate per extract)
3) Gel Base Preparation (Carbopol 940, glycerin, TEA)
4) Active Incorporation and Homogenization (homogenizer, 3000 rpm, 10 min)
5) Stability Testing and Evaluation

D. Physicochemical Evaluation

The formulated gels (three trial batches) were evaluated for the following parameters:

Parameter	Method / Equipment	Acceptance Criteria
pH	Digital pH meter (calibrated)	5.5 – 6.5
Viscosity	Brookfield viscometer (spindle 6)	4000 – 8000 mPa·s
Spreadability	Glass plate method (100 g load)	≥6 cm²/min
Antioxidant Activity	DPPH free-radical scavenging assay	$IC_{50} \leq 50$ µg/mL
Skin Hydration	Corneometer (Courage + Khazaka)	≥15% improvement over control
Irritation Score	Human repeat insult patch test (HRIPT)	Score ≤ 1 (no irritation)
Accelerated Stability	40°C / 75% RH, 3 months	No phase separation; pH ±0.3

Table 1. Evaluation parameters, methods, and acceptance criteria

E. Stability Testing Protocol

Accelerated stability studies were conducted per ICH Q1A(R2) guidelines at 40°C ± 2°C and 75% ± 5% relative humidity for three months. Batch-to-batch consistency was assessed by mean ± SD calculations, and comparative analysis between trial batches was performed using one-way ANOVA ($p < 0.05$ considered significant).

F. Bias and Variability Control

To minimize formulation bias, all herbal extracts were standardized to defined marker compounds before use. Fixed concentration ranges were maintained across batches. Excessive concentration of any single active was avoided to prevent antagonistic interactions. All evaluations were performed in triplicate.

III. RESULTS AND DISCUSSION

A. Organoleptic and Physical Properties

All three trial batches yielded a clear to slightly translucent, light-green gel with a characteristic pleasant herbal aroma. The texture was smooth, non-sticky, and non-greasy, with rapid skin absorption confirmed by qualitative assessment. No phase separation, discolouration, or syneresis was observed at baseline.

B. Physicochemical Evaluation Results

Parameter	Batch 1 (Mean ± SD)	Batch 2 (Mean ± SD)	Batch 3 (Mean ± SD)
pH	6.1 ± 0.05	6.0 ± 0.07	6.2 ± 0.04
Viscosity (mPa·s)	5820 ± 112	5960 ± 98	5740 ± 130
Spreadability (cm^2/min)	7.4 ± 0.3	7.6 ± 0.2	7.2 ± 0.4
DPPH IC_{50} (µg/mL)	38.2 ± 1.4	36.9 ± 1.8	39.5 ± 1.2
Hydration Improvement (%)	18.3 ± 2.1	19.1 ± 1.7	17.8 ± 2.4
Irritation Score (HRIPT)	0 (no reaction)	0 (no reaction)	0 (no reaction)

Table 2. Physicochemical evaluation results across three trial batches (n = 3)

C. Antioxidant Activity

The DPPH free-radical scavenging IC_{50} values (36.9–39.5 µg/mL) indicate potent antioxidant activity, attributable to the synergistic contribution of curcumin, EGCG from green tea, and natural Vitamin E. These values compare favourably with previously reported herbal gels in the literature [8,9].

D. Stability

Accelerated stability studies at 40°C/75% RH over three months revealed no significant change in pH (variation within ±0.2 units), viscosity, or appearance in any batch. This confirms the physicochemical compatibility of the herbal actives with the Carbopol gel base and the adequacy of natural stabilizers employed.

E. Discussion

The protective mechanism of the Anti-Herbal Skin Shield Gel operates through three synergistic pathways: (i) free-radical neutralization by polyphenols and tocopherols, preventing oxidative damage from UV and pollution-generated reactive oxygen species; (ii) formation of a breathable polysaccharide film on the skin surface that acts as a physical barrier against particulate pollutants; and (iii) antimicrobial action by neem and tulsi components, protecting the skin microbiome. The absence of irritation across all patch-test subjects and the measurable improvement in skin hydration further support both the safety and functional efficacy of the formulation.

IV. CONCLUSION

The study successfully demonstrated the formulation and evaluation of an Anti-Herbal Skin Shield Gel as a safe and effective alternative to conventional synthetic skin protectants. The optimized formulation exhibited desirable physicochemical properties, significant antioxidant activity, excellent stability, and no signs of skin irritation. The synergistic action of multiple herbal bioactives provided protection against environmental stressors such as pollution, UV radiation, and microbial exposure while enhancing skin hydration and barrier function. Overall, the findings support the potential of plant-based cosmeceuticals as sustainable, multifunctional solutions for modern skin protection.

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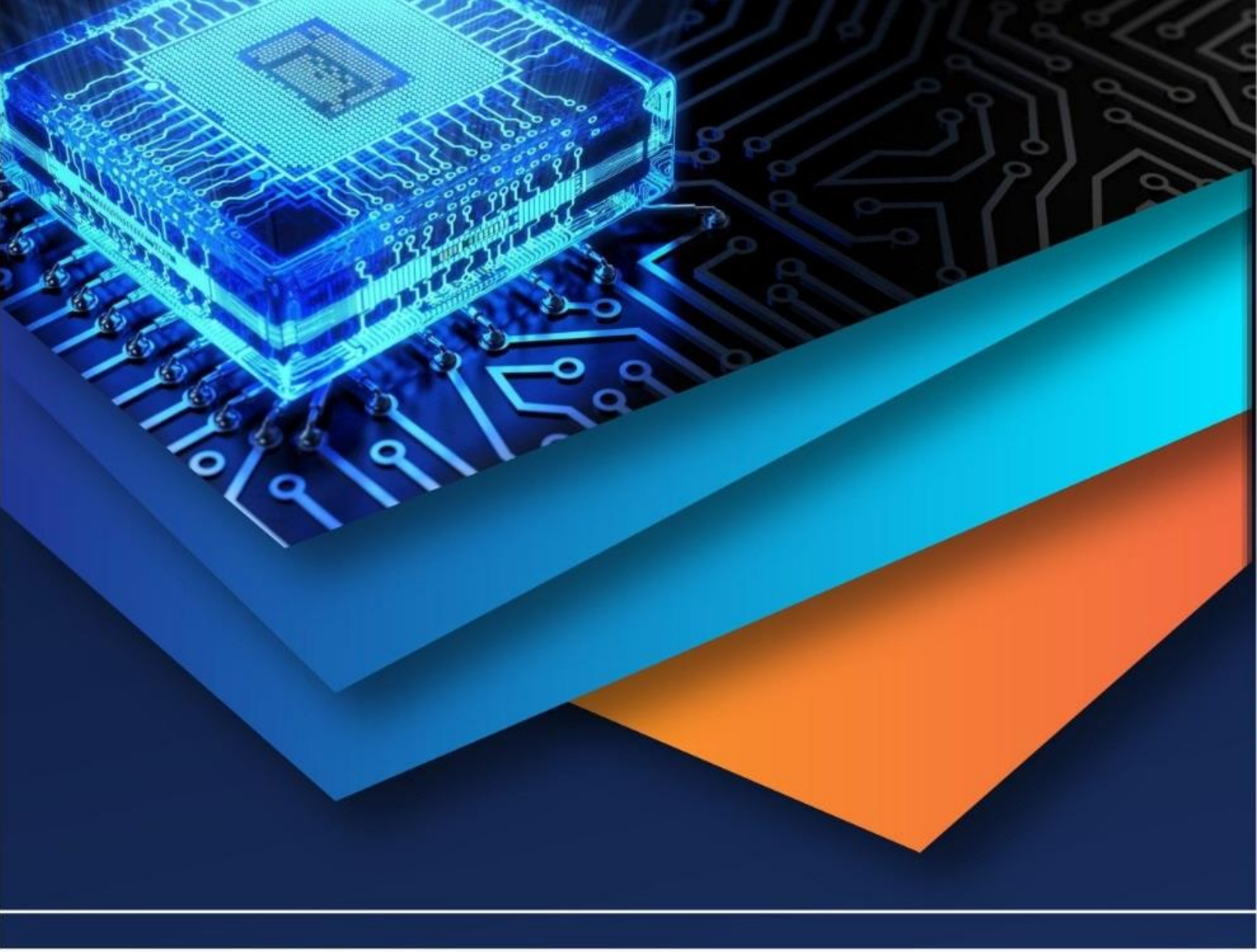

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