Formulation And Evaluation of Herbal Under Eye Roll on for Management of Periorbital Puffiness

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***Abstract*—Periorbital puffiness, characterized by localized edema and fluid retention in the under-eye area, remains a significant cosmetic concern due to the naturally delicate structural matrix of periorbital skin. This study outlines the formulation, optimization, and comprehensive evaluation of a stable, non-greasy herbal under-eye roll-on gel utilizing a synergistic blend of Centella asiatica, Camellia sinensis, Aesculus hippocastanum extracts, and Eucalyptus globulus oil. A series of trial batches (F1–F3) were developed using Carbopol 940 as a rheological modifier. The optimized batch (F2) demonstrated excellent homogeneity, a skin-compatible pH of 5.05, and an optimized average viscosity of 1030 cP exhibiting pseudoplastic flow. In-vitro occlusivity testing demonstrated a 74.4% reduction in water loss, indicating superior barrier protection. Dermal safety was established through a comprehensive 24-hour human patch test showing zero signs of erythema, irritation, or edema. Accelerated stability studies confirmed that the formulation retains its organoleptic and physicochemical parameters across diverse temperature profiles over time. The clinical utility is enhanced by the mechanical roll-on application, which facilitates lymphatic drainage and microvascular vasoconstriction via a targeted cryo-cooling effect.**

***Index Terms*—Aesculus hippocastanum, Carbopol 940, Centella asiatica, Cryo-Cooling, Periorbital Puffiness, Under-Eye Roll-On.**

I. INTRODUCTION

Human skin functions as the largest organ and protective barrier of the body [17]. It is composed of three distinct physiological layers: the epidermis, dermis, and hypodermis [2]. The periorbital region represents one of the thinnest and most sensitive sections of the facial skin matrix [2]. Structurally, it features a highly reduced dermal thickness, lower density of structural collagen and elastin fibers, and a minimal subcutaneous hypodermal adipose tissue reservoir [3]. This anatomical architecture makes the under-eye region highly vulnerable to localized interstitial fluid accumulation, microvascular congestion, and visible sagging, collectively recognized as periorbital puffiness [4].

The progression of under-eye swelling is heavily driven by modern lifestyle constraints, including chronic sleep deprivation, mental stress, fatigue, dehydration, high salt intake, and prolonged digital screen exposure [4]. These external and internal stressors trigger an overproduction of reactive oxygen species (ROS) [7]. The resulting oxidative stress damages cellular lipids and structural proteins, accelerating the degradation of collagen and elastin fibers by activating matrix metalloproteinase enzymes [7]. This destruction compromises capillary walls, increases vascular permeability, and facilitates fluid retention in periorbital tissues [3].

Conventional topical cosmetic preparations often rely on synthetic chemicals that carry a significant risk of secondary dermal irritation, dryness, or sensitivity when applied over prolonged periods near the delicate eye area [8]. Plant-based cosmeceuticals offer a safe, biocompatible alternative by delivering multi-targeted

biological activities with minimal adverse reactions [9].

This study introduces a stable, non-greasy herbal cryo-cooling under-eye roll-on gel containing extracts of Centella asiatica, Camellia sinensis (green tea), Aesculus hippocastanum (horse chestnut), and eucalyptus oil. Centella asiatica serves as a microcirculation enhancer and skin repair agent by stimulating collagen synthesis [1]. Camellia sinensis provides strong antioxidant and anti-inflammatory protections against environmental oxidative stress [5]. Aesculus hippocastanum exhibits potent anti-edematous activity by strengthening capillary walls to limit tissue fluid leakage [10]. Eucalyptol, derived from eucalyptus oil, delivers an instantaneous cryo-cooling and soothing sensation [11]. When dispensed through a mechanical roll-on ball applicator, this targeted delivery system applies a gentle massage effect that improves localized blood circulation and enhances lymphatic drainage to reduce swelling [12], [13].

II. MATERIALS AND METHODS

A. Raw Materials and Procurement

Active botanical components including Centella asiatica extract, Camellia sinensis extract, Aesculus hippocastanum extract, and volatile eucalyptus oil were procured to serve as active herbal ingredients. Excipients used for the polymer gel backbone and structural stabilization included Carbopol 940 (gelling polymer agent), Glycerin (humectant moisturizer), Propylene Glycol (solvent and penetration enhancer), Triethanolamine (neutralizing agent), and Sodium Benzoate (antimicrobial preservative). Distilled water was utilized as the baseline vehicle and solvent medium for uniform mixing.

B. Composition Matrix of Trial Formulations

To optimize the hydrogel structure, three independent prototype trial batches (F1, F2, and F3) were formulated by selectively varying the concentrations of Carbopol 940, humectant solvents, and active herbal extracts [16].

Table I: Formulation Optimization Table for Trial Batches (per 40 mL Batch)

S. No.	Ingredient	Category / Function	Trial F1	Trial F2 (Optimized)	Trial F3
1	Centella asiatica	Microcirculation Enhancer	1 mL	2 mL	3 mL
2	Camellia sinensis	Antioxidant Extract	1 mL	1.5 mL	2 mL
3	Aesculus hippocastanum	Anti-edematous Agent	1 mL	1.5 mL	2 mL
4	Eucalyptus oil	Cryo-cooling Active	1.5 mL	2 mL	2.5 mL
5	Carbopol 940	Gelling Polymer Base	0.5 gm	0.8 gm	1 gm
6	Glycerin	Humectant/ Moisturizer	2 mL	3 mL	4 mL
7	Propylene glycol	Co-solvent/ Permeation Booster	2 mL	3 mL	4 mL
8	Sodium Benzoate	Antimicrobial Preservative	1.5 mL	2 mL	2.5 mL
9	Triethanolamine	Neutralizing Agent	2 mL	3 mL	4 mL
10	Distilled Water	Vehicle Base Medium	q.s. 40 mL	q.s. 40 mL	q.s. 40 mL

C. Quantitative Batch Formula Scaling

The finalized composition of the optimized formulation was scaled quantitatively to prepare a standard 100 g production batch size [17].

Table II: Master Formula Composition Matrix (per 100 g Total Mass)

S. No.	Ingredient Specified	Operational Function in Matrix	Quantity (g)
1	Centella asiatica extract	Microcirculation enhancer, skin repair	2 g
2	Camellia sinensis extract	Antioxidant, anti-inflammatory	2 g
3	Aesculus hippocastanum extract	Anti-edematous, reduces puffiness	1.5 g
4	Eucalyptol (from Eucalyptus oil)	Cryo-cooling and soothing effect	0.3 g
5	Carbopol 940	Gelling polymer agent	0.5 g
6	Glycerin	Humectant moisturizer	5 g
7	Propylene glycol	Solvent and penetration enhancer	5 g
8	Triethanolamine	Neutralizing agent (pH adjustment)	0.4 g
9	Sodium benzoate	Antimicrobial preservative	0.5 g
10	Distilled water	Vehicle base medium	q.s. to 100 g

D. Manufacturing Methodology and Gel Formulation Steps

The preparation of the herbal under-eye roll-on formulation was carried out using a structured gel formulation method divided into clear processing steps [16]:

1. Preparation of Herbal Extract Phase: Measured quantities of Centella asiatica, Camellia sinensis, and Aesculus hippocastanum extracts were dispersed uniformly into a portion of distilled water under continuous stirring until fully dissolved.
2. Preparation of Gel Base: Carbopol 940 was sifted slowly into distilled water under continuous mechanical agitation to prevent the formation of macro-lumps, then allowed to hydrate completely for polymer swelling.
3. Preparation of Humectant Phase: Glycerin and propylene glycol were mixed in a separate beaker, and the active herbal phase was slowly incorporated under continuous stirring to ensure homogeneity.
4. Addition of Cooling Agent: Eucalyptus oil was added dropwise into the herbal-humectant solution with uniform stirring to distribute the volatile cryo-cooling components.
5. Incorporation into Gel Base: The compiled active phase was added gradually into the hydrated Carbopol gel base with continuous structural mixing.
6. Adjustment of pH and Gelation: Triethanolamine was added dropwise under uniform mechanical stirring to neutralize the polymer base, building a smooth, clear hydrogel structure.
7. Preservation and Final Volume Adjustment: Sodium benzoate was dissolved into the gel network to ensure microbial stability. The final volume was adjusted using distilled water, mixed thoroughly, and filled into sterilized roll-on containers.

III. EVALUATION PARAMETERS AND RESULT

A. Reformulation Baseline Parameters

Initial parameters were confirmed via reformulation analysis to verify initial raw material specifications before proceeding with optimization [17]. Color assessment was conducted via visual inspection against a clear background, odor profiles were checked via sensory evaluation panels, and pH was monitored using a digital pH meter.

Table III: Preformulation Parameters Reference Matrix

Sr. No.	Parameter Checked	Evaluation Methodology	Observed Baseline
1	Colour	Visual Inspection	Creamish white
2	Odour	Sensory Evaluation	Pleasant odour
3	Appearance	Visual Inspection	Smooth gel
4	pH	Digital pH Meter	5.05
5	Viscosity	Brookfield Viscometer	Moderate viscosity
6	Spreadability	Parallel Glass Slide Method	5-25 gm·cm/s
7	Homogeneity	Visual Observation	Uniform
8	Washability	Manual Washing Test	Easily washable
9	Consistency	Manual Tactile Inspection	Smooth consistency

B. Organoleptic and Physical Profiling

Organoleptic evaluations of the optimized F2 batch confirmed excellent consumer acceptability. The gel maintained a smooth, semi-solid consistency and creamish white color due to the combined plant oils and natural extracts. Tactile assessment verified a soft, non-greasy texture that distributed uniformly upon application. The hydrogel exhibited complete structural homogeneity without any observable macro-particulates, lumps, or phase separation.

C. Digital pH Analysis

Dermal safety near periorbital tissue depends heavily on maintaining a skin-compatible pH profile [2]. One gram of the final formulation was thoroughly dispersed in 100 mL of neutral distilled water and tested using a calibrated digital pH meter.

Table IV: Digital pH Evaluation of the Formulated Gel Matrix

S. No. Run	Observed Digital pH Value	Final Data Interpretation
1	5.25	Within safe guidelines
2	5.05	Skin-compatible level
3	5.05	Prevents localized irritation

Average Result	5.05	Highly compatible with skin mantle

D. Rheological Viscosity Studies

The structural flow behavior of the optimized hydrogel was measured using a digital Brookfield Viscometer at room temperature to evaluate application suitability through a roll-on bottle [16].

Table V: Viscosity Profiling Across Variable Shearing Rates

Spindle Rotational Speed (RPM)	Measured Dynamic Viscosity (mPa·s / cP)
6 RPM	1100
12 RPM	1030 (Log Representative Average)
30 RPM	1000

The formulation demonstrated clear pseudoplastic (shear-thinning) non-Newtonian flow properties [16]. As the spindle rotational speed increased from 6 RPM to 30 RPM, the systemic viscosity dropped from 1100 cP to 1000 cP. This rheological behavior ensures the gel remains securely structured inside the roll-on bottle at rest, but flows smoothly under the mechanical shear applied by the moving roller ball during application.

E. Spreadability and Washability Index

Spreadability testing using the parallel glass slide technique showed an optimal spread range of 5–25 g·cm/s, ensuring uniform application across sensitive under-eye skin without pulling or stretching. Manual washability testing confirmed the hydrogel is completely water-soluble and can be removed cleanly with tap water without leaving behind a heavy, sticky, or greasy lipid layer [17].

F. In-Vitro Occlusivity Analysis

An in-vitro occlusivity test was carried out gravimetrically using a semipermeable membrane covering a fixed water reservoir to gauge moisture protection performance [18]. The formulation achieved an occlusive index of 74.4%. This indicates the hydrogel builds a micro-barrier across the stratum corneum that blocks excessive evaporation, retaining localized hydration to plump and refresh the periorbital skin matrix [18].

G. In-Vivo Dermal Safety Patch Testing

To ensure the biological compatibility of the herbal roll-on gel prior to periorbital use, a localized patch test was conducted on human volunteer skin over a 24-hour monitoring period [8].

Table VI: Dermal Safety Patch Test Tolerance Matrix

Observation Parameter Checked	Prior to Application	5 Minutes Post-App	24 Hours Post-App
Localized Erythema (Redness)	Absent	Absent	Absent
Cutaneous Irritation	Absent	Absent	Absent
Local Pruritus (Itching)	Absent	Absent	Absent
Dermal Edema (Swelling)	Absent	Absent	Absent
Subjective Burning Sensation	Absent	Absent	Absent

The data confirmed excellent topical safety, with zero adverse events logged across all check intervals [8]. The complete lack of irritation or redness indicates the formulation is safe for application near sensitive under-eye skin zones.

H. Accelerated Stability Testing

To determine the physical and chemical shelf-life stability of the finalized product, the F2 batch was stored under varying environmental stress conditions and examined periodically [16].

Table VII: Parametric Variations Under Accelerated Environmental Stress

Evaluation Parameter	Room Temperature (25°C)	Refrigerated Cold (2–5°C)	Accelerated Heat (40°C)
Structural Color	No change	No change	No change
Organoleptic Odor	No change	No change	No change
Physical Consistency	Smooth gel	Smooth gel	Smooth gel
Phase Separation / Syneresis	Absent	Absent	Absent
Stability pH Level	4.6	4.6	4.8
Spreadability Coefficient	4.5×10^{-2} g.cm/s	4.5×10^{-2} g.cm/s	4.5×10^{-2} g.cm/s

The accelerated stability studies confirmed the formulation's physical resilience [16]. Subjecting the gel to thermal stress caused no cracking, syneresis, or phase separation. Minor shifts in pH (4.6 to 4.8) and spreadability constants remained well within standard pharmaceutical variance parameters, confirming a stable shelf-life.

IV. CONCLUSION

A stable, safe, and cosmetically acceptable herbal under-eye roll-on gel was successfully developed and optimized. The optimized batch (F2) fulfilled all target rheological specifications, exhibiting pseudoplastic behavior (1030 cP), a skin-compatible pH (5.05), and excellent accelerated thermal stability. The combination of active botanical extracts (Centella asiatica, Camellia sinensis, and Aesculus hippocastanum) working in synergy with eucalyptus oil provides a comprehensive approach to managing periorbital puffiness by targeting oxidative damage, reducing tissue edema, and strengthening capillary networks [1], [5], [10].

Additionally, the hydrogel's non-greasy texture, high occlusive protection index (74.4%), and excellent skin safety profile validate its potential as a functional plant-based alternative to synthetic cosmeceuticals [8], [18]. Administered via a rolling applicator delivery system, the formulation thins under pressure to provide uniform application while combining a refreshing cryo-cooling sensory effect with a localized massage action [12], [13]. This combined approach encourages localized vasoconstriction and fluid clearance, offering an effective option for cosmetic periorbital care.

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