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FORMULATION AND EVALUATION OF A POLYHERBAL BIO-MASK FOR COMPREHENSIVE SCALP AND HAIR THERAPEUTICS

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ABSTRACT

Background: Modern lifestyle alterations, elevated physiological stress, chemical exposure from synthetic hair cosmetics, and environmental stressors have drastically heightened the incidence of hair pathologies such as trichoptilosis (split ends), alopecia (hair fall), premature greying, and seborrheic dermatitis (dandruff). Synthetic formulations often introduce harsh surfactant residues and chemical toxins that exacerbate hair shaft brittleness and trigger scalp inflammation. **Objective:** This study aimed to formulate and comprehensively evaluate an all-natural, biodegradable polyherbal hair mask optimized to synergistically enhance hair shaft strength, reduce hair fall, mitigate dandruff, and restore natural shine without causing dermal irritation.

KEYWORDS: Polyherbalism, Hair Therapeutics, Trichology, Bio-Mask, Scalp Seborrhea, Formulation Optimization.

1. INTRODUCTION

Hair functions as a crucial proteinaceous biomaterial principally composed of high-sulfur α-keratin cross--linked via disulfide bonds.[1]

From a physiological standpoint, hair filaments arise from complex epithelialmesenchymal interactions within the dermal papilla of hair follicles situated in the dermis layer of mammalian skin.[2] Beyond its significant psycho-social correlation to human aesthetics, self-esteem, and general well-being, hair serves pivotal evolutionary biological roles, including cephalic thermal insulation, protection against ultraviolet radiation, and sensory perception.[3]

1.1 Physiology of the Hair Growth Cycle

The lifecycle of human hair follicles is highly dynamic and operates under a continuous, asynchronous cyclic rhythm consisting of four distinct morphological phases.[2]

- **Anagen Phase:** The active mitotic and proliferative stage during which the follicle base deepens within the dermis, receiving heavy vascular nourishment to sustain long-term elongation of the hair shaft. Approximately 85–90% of healthy scalp follicles exist in this state simultaneously.[2]
- **Catagen Phase:** A brief, highly regulated regressive transition period marked by the cessation of matrix cell proliferation and the structural detachment of the hair follicle from its underlying dermal vascular supply.[2]
- **Telogen Phase:** A metabolic resting phase during which the hair strand remains structurally quiescent as a "club hair" within the follicle. Under steady-state physiological dynamics, roughly 9% of scalp follicles occupy this phase.[2]
- **Exogen Phase:** The final shedding event wherein the older hair shaft falls away to permit the initiation of a new anagen lineage by the underlying follicular stem cells.[2]

This complex biological clock is profoundly influenced by systemic dietary choices, hormonal fluxes (specifically dihydrotestosterone modulation), advancing age, and psycho-emotional stress markers.[2,3]

1.2 Structural Anatomy of the Hair Shaft

The extra-follicular hair shaft is organised into three distinct concentric cellular cylinders:[3]

- **The Cuticle:** The outermost protective layer consisting of translucent, heavily keratinised, dead squamous cells that overlap in a highly ordered, imbricated pattern resembling roof tiles. A healthy cuticle maintains structural hydrophobic integrity, minimizes internal matrix moisture loss, and reflects light to give hair its natural shine.[3]
- **The Cortex:** The intermediate layer forming the bulk of the hair shaft mass. It comprises elongated, parallelaligned cortical cells packed with tightly bundled keratin intermediate filaments embedded within an amorphous matrix. The cortex dictates the mechanical tensile strength, elastic flexibility, and structural configuration of the hair, and houses melanin granules responsible for hair pigmentation.[3]
- **The Medulla:** The innermost central core, which is highly porous and characterized by loosely arranged cells punctuated by vacuum-like air spaces. The presence and continuity of the medulla are highly variable across different human ethnicities and fine hair categories.[3]

1.3 The Rationale for Polyherbal Bio-Masks

The prevalence of universal hair disorders encompassing seborrheic dermatitis (dandruff), unmanageable frizz, trichoptilosis (split ends), accelerated graying, and telogen effluvium (hair loss) has escalated due to widespread reliance on chemical-laden hair products.[4,5] Synthetic anti-dandruff shampoos and chemical conditioning masks often incorporate zinc pyrithione, selenium disulfide, synthetic silicones, and formaldehyde releasing parabens.[6]

Over time, these compounds accumulate on the hair cuticles, strip the natural sebum layer, induce contact dermatitis, and cause structural damage that renders the hair shaft brittle and prone to split ends.[6,7]

To circumvent these adverse outcomes, green cosmetic chemistry emphasizes polyherbalism—the strategic formulation of diverse botanical extracts to create a therapeutic synergy that outperforms single-herb isolates.[8] An herbal hair mask functions as an eco-friendly, biodegradable, non-toxic topical treatment designed to deliver bioactive molecules directly

to the scalp and hair cuticle.[9] This study designs a polyherbal mask to supply crucial phytonutrients, reinforce the hair cuticle barrier, clear microbial buildup, and optimize structural vitality without chemical side effects.

2. MATERIALS AND METHODOLOGY

2.1 Botanical and Material Sourcing

All raw plant materials were collected from verified botanical sources to ensure authentic, unadulterated species profiles. The primary materials and instruments utilized in this research are cataloged in Tables 1 and 2 below.

Table 1: Physicochemical and Botanical Raw Material Inventory.

No.	Material Name / Common Name	Primary Functional Assignment in Mask	Source form
1	*Emblica officinalis* (Amla) +	Antioxidant, Melanogenesis Promoter, Vitamin C Source	Fine Powder
2	*Azadirachta indica* (Neem)	Antimicrobial, Anti-seborrheic, Scalp Purifier	Fine Powder
3	*Ficus benghalensis* (Banyan Root)	Follicular Anchor, Tensile Strength Fortifier	Fine Powder
4	*Nigella sativa* (Kalonji)	Nutrient Vehicle, Antimicrobial, Root Stimulator	Fine Powder
5	*Trigonella foenum-graecum* (Methi)	Demulcent Mucilage, Cuticle Smoother, Protein Source	Fine Powder
6	*Aloe barbadensis* (Aloe Vera Gel)	Hydrating Hydrogel Base, Enzyme Restorator, Soother	Fresh Leaf Extract
7	*Linum usitatissimum* (Linseed Gel)	Film-forming Polymer Base, Frizz Controller	Viscous Hydrogel
8	*Ricinus communis* (Castor Oil)	Hydrophobic Emollient, Lipophilic Nutrient Penetrator	Cold-pressed Oil
9	Methyl Paraben	Broad-spectrum Antimicrobial Preservative	Crystalline Powder
10	*Rosa damascena* (Rose Oil)	Natural Fragrance Modulator, Therapeutic Essential Oil	Steam Distillate

Table 2: Analytical Equipment Specifications.

INSTRUMENT NAME	MANUFACTURER / MODEL CONFIGURATION	FUNCTIONAL DOMAIN
Digital pH Meter	SYSTRONIC pH System 361	Electro-analytical Potentiometric Hydrogen Ion Mapping

2.2 Formulation Protocol

The polyherbal hair mask was prepared utilizing precise mass measurements to ensure a stable, homogenous gel-paste system as defined in Table 3.

Table 3: Quantitative Composition Matrix of Master Formulation.

NO.	INGREDIENT COMPONENT	QUANTITATIVE MASS / VOLUME	PERCENTAGE (W/W)
1	Amla Powder (*Emblica officinalis*)	4.0 mg	6.14%
2	Banyan Tree Root Powder (*Ficus benghalensis*)	4.0 mg	6.14%
3	Fenugreek Seed Powder (*Trigonella foenum-graecum*)	4.0 mg	6.14%
4	Kalonji Seed Powder (*Nigella sativa*)	4.0 mg	6.14%
5	Neem Leaf Powder (*Azadirachta indica*)	4.0 mg	6.14%
6	Fresh Aloe Vera Gel (*Aloe barbadensis*)	22.0 mg	33.79%
7	Linseed Hydrogel Mucilage (*Linum usitatissimum*)	12.0 mg	18.43%
8	Cold-Pressed Castor Oil (*Ricinus communis*)	8.0 mg	12.29%
9	Methyl Paraben Preservative	0.1 mg	0.15%
10	Pure Rose Essential Oil (*Rosa damascena*)	3.0 ml	4.61%
-	**Master System Composite Total**	**65.1 mg equiv.**	**100.00%**

Step-by-Step Production Sequence

1. **Base Polymer Hydration:** Freshly strained Aloe vera gel and *Linum usitatissimum* linseed gel were combined in a clean vessel and mixed until they formed a smooth, uniform hydrogel base.
2. **Solid Phase Dispersion:** Carefully weighed quantities (4.0 mg each) of finely milled Amla, Banyan root, Fenugreek, Kalonji, and Neem powders were slowly added to the hydrogel base. The mixture was stirred

continuously to prevent clumps and ensure uniform wetting of the particles.

3. **Lipophilic Incorporation:** Cold-pressed castor oil was slowly poured into the mixture along with the dissolved methyl paraben preservative. The blend was mixed thoroughly to evenly disperse the lipophilic droplets throughout the hydrophilic gel network.
4. **Olfactory Optimization:** *Rosa damascena* essential oil was stirred in during the final step to provide a pleasing aroma and finish the mask preparation. The resulting gel-paste was filled into air-tight containers for evaluation.

3. EVALUATION AND RESULTS

The completed polyherbal mask formulation was evaluated through physical, chemical, and biological performance tests.

3.1 Organoleptic Characterization

The sensory attributes of the mask were assessed to ensure a high level of cosmetic elegance and user compliance. The results are detailed in Table 4.

Table 4: Organoleptic Test Observations

Assessment Parameter	Visual / Olfactory Analytical Response	Evaluation Status
Colour Profile	Consistent, deep charcoal black	Highly Satisfactory
Texture & Feel	Smooth, cohesive gel-paste with no grittiness	Highly Satisfactory
Odour Signature	Soothing, clean floral rose aroma	Highly Satisfactory

3.2 Physicochemical Screenings

1. **Potentiometric pH Mapping:** The pH value was measured using a calibrated digital SYSTRONIC 361 pH meter at an ambient temperature of ***25°C***. The mask demonstrated a stable pH value of ***4.84***. This slightly acidic profile matches the natural acid mantle of the human scalp and hair (which typically ranges from ***4.5*** to ***6.0***). Maintaining this biological balance is crucial to prevent scalp irritation, minimize the risk of cuticle damage, and help maintain the hair's natural cuticle structure.
2. **Homogeneity and Visual Phase Separation:** The formulation was inspected visually under intense direct light and spread as thin layers across clean glass slides. It showed excellent structural homogeneity, with the botanical powders evenly suspended throughout the gel base and no signs of syneresis or phase separation during storage.
3. **Spreadability and Rheological Behaviour:** The mask demonstrated a highly favourable rheological profile. When evaluated using a specialised spreadability apparatus, it demonstrated good spreadability across the testing surface under minimal shear force. This ensures a smooth, even application over both the hair strands and the scalp surface.
4. **Washability Dynamic Profile:** Samples of the mask were applied to surfaces and hair tresses. The findings showed that the herbal hair mask was easily removed from the surface by the simple application of water. This property confirms that the formulation is highly user-friendly and does not leave behind any stubborn or sticky residue.

3.3 Dermal Irritancy and Safety Screening

To verify that the polyherbal mask is completely non-toxic and safe for sensitive skin, a human patch test was conducted. A small amount of the formulated paste was applied to the skin of healthy volunteers. The patches were monitored over a set period for adverse skin reactions, and observations are recorded in Table 5.

Table 5: Human Dermal Irritancy Profile.

POTENTIAL DERMAL REACTION	OBSERVED RESPONSE (IMMEDIATE)	OBSERVED RESPONSE (AFTER 24 HOURS)
Irritance	No	No
Edema	No	No
Redness	o	No
Swelling	No	No

No volunteer experienced any signs of irritation, redness, or swelling during the testing period. This confirms that the formulation is highly biocompatible and safe for regular topical application on the human scalp.

4. DISCUSSION

The experimental results demonstrate that combining these specific botanical extracts within a blended hydrogel base successfully creates a highly functional, stable, and cosmetically elegant polyherbal hair mask. Each ingredient contributes to the overall success of the formulation. The fresh *Aloe barbadensis* and *Linum usitatissimum* gels form a stable, hydrating network that delivers active compounds effectively while allowing the mask to rinse away easily without synthetic detergents.[5,14] Incorporating a precise amount of cold-pressed castor oil provides a natural emollient effect, smoothing down rough cuticle scales to reduce frizz and lock in deep moisture.

From a therapeutic standpoint, this hair mask targets multiple scalp and hair concerns simultaneously. The antimicrobial properties of *Azadirachta indica* (Neem) and *Nigella sativa* (Kalonji) help eliminate the fungal microflora responsible for dandruff, relieving an itchy, flaky scalp.[11,12] At the same time, the antioxidant-rich *Emblica officinalis* (Amla) neutralises free radicals around the hair roots,[10] while the structural compounds in *Ficus benghalensis* (Banyan root) help firm the surrounding skin tissues to strengthen hair anchoring and reduce shedding.[15] Crucially, the mask's measured pH value of 4.84 perfectly complements the scalp's natural acid mantle, avoiding the irritation and structural cuticle damage often caused by harsh, alkaline chemical treatments.

The patch test results confirmed the complete absence of skin irritation, proving that this chemical-free polyherbal mask offers a safe, effective, and sustainable alternative to synthetic hair conditioners and scalp treatments.

5. CONCLUSION

The herbal hair mask's potential as a safe and efficient substitute for commercial hair care products was verified by its successful development and testing. Improved hair strength, less dandruff, more shine, and less hair loss were among the synergistic effects achieved by the strategic combination of specific herbal substances such as amla, banyan tree root, kalonji, fenugreek, and neem. The formulation's safety, usability, and stability under typical storage settings were validated by the structural assessment parameters, which included pH, spreadability, washability, stability, and sensory analysis. All things considered, the herbal hair mask turned out to be a viable, economical, and environmentally responsible way to maintain hair health without using dangerous synthetic chemicals. Its clinical effectiveness can be further consolidated and its demographic use expanded with the support of additional long-term clinical research and user trials.

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