Design, Formulation and Evaluation of a Polyherbal Hair Serum with Enhanced Hair Care Properties

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***Abstract*—The main aim of the present work is to formulate and evaluate a herbal hair serum using natural plant-based oils for cosmetic and therapeutic hair care. Hair loss, dandruff, premature greying, and scalp disorders have become increasingly prevalent due to environmental pollution, nutritional deficiencies, and excessive use of chemical-based hair care products. Herbal formulations offer a safer, gentler, and more sustainable alternative. According to Grand View Research, the global cosmetics market was valued at USD 262.21 billion in 2022 and is projected to grow at a CAGR of 4.2% through 2030, reflecting the rising demand for natural cosmetic products. The herbal hair serum was developed using a blend of eight phytochemically rich oils: *Cocos nucifera* (Coconut oil), *Prunus dulcis* (Almond oil), *Phyllanthus emblica* (Amla oil), *Azadirachta indica* (Neem oil), *Aloe barbadensis* (Aloe vera oil), *Salvia rosmarinus* (Rosemary oil), *Lavandula angustifolia* (Lavender oil), and Tocopherol (Vitamin E) oil. Three batches (B1, B2, B3) were prepared and evaluated for physical appearance, pH, viscosity, homogeneity, spreadability, stability, and irritation. The optimized formulation (Batch 3) was found to be clear, stable, non-irritant with a pale yellow to greenish colour, pleasant aromatic odour, and a pH of ~5.5. The serum demonstrated excellent scalp compatibility, reduced dandruff, strengthened hair roots, and promoted hair growth. This study validates the potential of herbal oil blends as effective, safe, and commercially viable hair care formulations.**

***Index Terms*—Hair serum, herbal cosmetics, *Cocos nucifera, Phyllanthus emblica, Azadirachta indica, Aloe barbadensis, Salvia rosmarinus*, hair loss, alopecia, dandruff, phytochemistry, topical formulation, scalp health, antioxidant, antimicrobial, physicochemical evaluation.**

I. INTRODUCTION

Hair is one of the most visible and defining features of a person's appearance, playing a vital role in self-expression and cultural identity. It also serves important biological functions including regulation of body temperature and protection of the scalp from external insults. Hair loss, dandruff, premature greying, and other scalp-related disorders have emerged as significant cosmetic and clinical concerns globally. [19, 20]

Hair problems such as alopecia, androgenetic hair loss, telogen effluvium, and seborrheic dermatitis affect a considerable proportion of the population, with lifestyle factors such as stress, poor nutrition, pollution, and overuse of chemical hair products being key contributors. [21, 22] Conventional hair care products, though effective, often contain synthetic chemicals such as sulfates, silicones, and parabens, which may cause allergic reactions, scalp irritation, and cumulative toxicity with prolonged use.

Herbal cosmetics, defined under Indian Standards IS 15735:2006 as products formulated using various permissible cosmetic ingredients to provide defined cosmetic benefits, have witnessed growing popularity. [7] The global herbal cosmetics market is expanding rapidly due to increased consumer awareness about the safety and efficacy of plant-derived ingredients. Phytochemical constituents found in medicinal plants—including flavonoids, polyphenols, vitamins, and essential fatty acids—have been shown to nourish the scalp, strengthen hair follicles, reduce oxidative stress, and promote healthy hair growth. [15]

The present study focuses on the formulation and evaluation of a polyherbal hair serum using eight carefully selected plant-derived oils. *Cocos nucifera*

(Coconut oil) penetrates the hair shaft and reduces protein loss. *Phyllanthus emblica* (Amla oil) is rich in Vitamin C, tannins, and polyphenols known to strengthen roots and prevent premature greying. [24] *Azadirachta indica* (Neem oil) exerts potent antimicrobial and anti-dandruff effects. *Aloe barbadensis* (Aloe vera oil) soothes scalp inflammation and promotes follicular health. *Salvia rosmarinus* (Rosemary oil) stimulates scalp microcirculation, while *Lavandula angustifolia* (Lavender oil) reduces stress-related hair fall and supports follicle growth. [26] Tocopherol (Vitamin E) oil acts as an antioxidant preserving formulation stability and protecting hair from oxidative damage.

The objective of this research is to develop an optimized herbal hair serum formulation and systematically evaluate it for physicochemical properties, safety, and efficacy to validate its potential as a commercially viable, natural hair care product.

II. MATERIALS

1) Coconut Oil (Cocos nucifera)

Coconut oil, derived from the kernel of *Cocos nucifera* (Family: Arecaceae), is a widely used fixed oil in herbal cosmetics. Synonymously known as Copra oil or Nariyal oil, it is predominantly composed of medium-chain fatty acids including lauric acid (major), myristic, palmitic, caprylic, capric, and oleic acids. These constituents confer antimicrobial, anti-inflammatory, and deep moisturizing properties. In hair care, coconut oil is particularly valued for its ability to penetrate the hair shaft—unlike most other oils—thereby reducing protein loss, preventing dandruff and breakage, and supporting healthy hair growth.

2) Almond Oil (Prunus dulcis)

Sweet almond oil (Badam oil) is obtained from the seeds of *Prunus dulcis* (Family: Rosaceae). Its chemical composition includes oleic acid (~60–70%), linoleic acid (~20–30%), palmitic acid (~5–10%), and Vitamin E. As an emollient and cosmetic oil, almond oil strengthens hair roots, prevents breakage, adds shine, and reduces dryness and dandruff. Its anti-inflammatory and antioxidant properties further contribute to scalp nourishment and overall hair health.

3) Amla Oil (Phyllanthus emblica)

Amla oil is derived from *Phyllanthus emblica* (syn. *Emblica officinalis*; Family: Phyllanthaceae), known as Indian gooseberry. It is classified as a herbal infused hair tonic with a slightly acidic pH (~3–5). Rich in Vitamin C, tannins, flavonoids, polyphenols, and fatty acids, amla oil demonstrates potent antioxidant and anti-inflammatory activity. It strengthens hair roots, promotes hair growth, prevents hair fall, adds shine and thickness, and is particularly noted for its role in preventing premature greying. [24]

4) Neem Oil (Azadirachta indica)

Neem oil is a fixed medicinal oil extracted from the seeds of *Azadirachta indica* (Family: Meliaceae), also known as Margosa oil. Its active constituents include azadirachtin, nimbin, nimbidin, and fatty acids (oleic, stearic, palmitic, and linoleic acids). These compounds impart strong antimicrobial and anti-inflammatory properties, making neem oil highly effective against dandruff, scalp infections, and lice. It strengthens hair roots, reduces hair fall, controls sebum secretion, and promotes a healthy scalp environment conducive to hair growth.

5) Aloe Vera Oil (Aloe barbadensis Miller)

Aloe vera infused oil is prepared from *Aloe barbadensis Miller* (Family: Asphodelaceae), known synonymously as Ghritkumari oil. Classified as a herbal emollient, it contains polysaccharides (acemannan), vitamins A, C, E, B12, enzymes, amino acids, minerals (zinc, magnesium), and fatty acids from the carrier oil. With a pH of ~4.5–5.5, aloe vera oil soothes scalp irritation, reduces dandruff, maintains scalp moisture, and promotes healthy follicular growth through its antimicrobial and anti-inflammatory mechanisms.

6) Rosemary Oil (Salvia rosmarinus)

Rosemary oil is a volatile essential oil obtained from *Salvia rosmarinus* (formerly *Rosmarinus officinalis*; Family: Lamiaceae). Its principal chemical constituents include 1,8-cineole (eucalyptol), camphor, α-pinene, borneol, and rosmarinic acid. These compounds provide antimicrobial and anti-inflammatory activity, improve scalp blood circulation, and reduce stress. Rosemary oil is particularly notable for stimulating scalp microcirculation, strengthening hair follicles, reducing

hair fall, and improving hair thickness and overall growth. [26]

7) Lavender Oil (Lavandula angustifolia)
Lavender essential oil is derived from *Lavandula angustifolia* (Family: Lamiaceae). Its primary constituents include linalool, linalyl acetate, terpinen-4-ol, lavandulol, and small amounts of camphor. Known for its calming, antimicrobial, anti-inflammatory, and wound healing properties, lavender oil improves scalp circulation, reduces stress-related hair fall, controls dandruff, promotes follicle growth, and strengthens hair structure.

8) Tocopherol (Vitamin E) Oil
Tocopherol (d-α-tocopherol in its natural form) is a fat-soluble antioxidant belonging to the group of tocopherols. It is classified as a cosmetic antioxidant and oil-soluble vitamin. Vitamin E oil protects skin and hair from oxidative damage, strengthens hair follicles, reduces breakage, adds shine, and maintains scalp integrity. In the present formulation, it was added to prevent rancidity of the oil-based serum and thereby enhance its shelf life.

III. METHODOLOGY

3.1 Procurement of Ingredients
All the herbal oils—Coconut oil, Almond oil, Amla oil, Neem oil, Aloe vera oil, Rosemary oil, Lavender oil, and Tocopherol (Vitamin E) oil—were procured from local herbal and cosmetic suppliers in Nashik, Maharashtra. All ingredients were authenticated and stored under appropriate conditions prior to formulation.

3.2 Preparation of Herbal Hair Serum
Three batches (B1, B2, B3) of 30 mL herbal hair serum were prepared using an optimized step-wise procedure:

- All required glassware (glass beaker, measuring cylinders, glass rods, and funnel) were cleaned and dried as per standard operating procedure (SOP).
- A base oil blend was prepared by combining coconut oil and almond oil, followed by gentle heating for 5 minutes at 40–50°C.
- Herbal oils (amla, neem, and aloe vera) were added to the base blend and the mixture was stirred thoroughly for 10 minutes to ensure uniform blending.
- The mixture was removed from heat and allowed to cool to room temperature. Essential oils (rosemary and lavender) were then added with gentle stirring for 3–5 minutes to preserve their volatile components.
- Vitamin E oil was incorporated last to prevent oxidative rancidity and increase shelf life. The formulation was stirred using a magnetic stirrer for 10–15 minutes to ensure a clear, uniform, lump-free oil blend.
- The serum was filtered through muslin cloth or filter paper to remove any suspended particles, then transferred into a 30 mL amber glass bottle sealed with a dropper or pump cap.

3.3 Formulation Batches
Table 2 to 4 show the composition of the three experimental batches.

Table 2. List of ingredients for hair serum – Batch 1 (B1)

Sr. No.	Name of Ingredient	Amount (mL)
1.	Coconut oil	10 mL
2.	Almond oil	8 mL
3.	Amla oil	5 mL
4.	Neem oil	2 mL
5.	Aloe vera oil	3 mL
6.	Rosemary oil	0.5 mL
7.	Lavender oil	1 mL
8.	Tocopherol (Vit E) oil	0.5 mL

Table 3. List of ingredients for hair serum – Batch 2 (B2)

Sr. No.	Name of Ingredient	Amount (mL)
1.	Coconut oil	8 mL
2.	Almond oil	5 mL

3.	Amla oil	7 mL
4.	Neem oil	3 mL
5.	Aloe vera oil	3 mL
6.	Rosemary oil	1.5 mL
7.	Lavender oil	2 mL
8.	Tocopherol (Vit E) oil	0.5 mL

Table 4. List of ingredients for hair serum – Batch 3 (B3)

Sr. No.	Name of Ingredient	Amount (mL)
1.	Coconut oil	7 mL
2.	Almond oil	10 mL
3.	Amla oil	4 mL
4.	Neem oil	1 mL
5.	Aloe vera oil	5 mL
6.	Rosemary oil	0.5 mL
7.	Lavender oil	2 mL
8.	Tocopherol (Vit E) oil	0.5 mL

3.4 Evaluation Parameters

Physical Appearance: The formulated serum was visually examined for colour, odour, and texture.

pH: A digital pH meter was calibrated with pH 4 and pH 7 buffer solutions. The electrode was immersed in the hair serum and allowed to stabilize before recording the pH value.

Viscosity: Viscosity was determined using a Brookfield Viscometer at 100 rpm with spindle model S6, using 4.5 mL of the serum. The spindle was allowed to equilibrate for 5 minutes before measurement.

Homogeneity Test: A small quantity of the serum was placed on a clean, dry glass slide and examined under light for the presence of coarse particles, lumps, flocculates, or aggregates.

Spreadability: Spreadability was evaluated using the parallel plate method. One gram of serum was pressed between two horizontal glass plates (20 × 20 cm), the upper plate weighing 125 g. The spread diameter was measured after 1 minute.

Stability Studies: The formulation was stored at room temperature and elevated temperature conditions. It was periodically examined for changes in colour, odour, texture, and physical appearance over the study period.

Irritancy Test: A small amount of the serum was applied to the inner forearm. The application site was observed for any signs of redness, itching, swelling, or irritation over 24 hours.

IV. RESULTS AND DISCUSSION

Herbal hair serums are gaining popularity in recent years due to their therapeutic efficacy, ease of use, and favourable safety profiles. The present study involved optimization of the formulation through three experimental batches with progressive improvements in processing technique.

Batch 1 (B1) – Preliminary Formulation:

The first batch was overheated during the preparation process, leading to degradation of active herbal constituents. The resultant oil showed a slightly darker colour and a mild burnt odour. While the batch showed acceptable pH (~5.5), homogeneity, and irritation test results, it was not considered satisfactory for further use.

Table 5. Results for Batch 1 trial for hair serum (B1)

Sr. No.	Characteristics	Appearance
1.	Colour	Pale yellow
2.	Odor	Mild herbal aroma
3.	Viscosity	Medium

4.	Homogeneity	Uniform, no separation
5.	Spreadability	Easy to apply
6.	pH	~5.5
7.	Stability	Stable at room temperature
8.	Irritation test	No redness or itching
9.	Hair application	Smooth, reduces hairfall moderately
10.	Overall suitability	Balanced daily use

Batch 2 (B2) – Modified Formulation:
In Batch 2, a controlled low-heat/double boiler method was adopted to address the overheating problem from Batch 1. However, filtration was found to be inadequate, resulting in the presence of fine herbal particles and slight turbidity. The formulation was deemed best for dry or damaged hair but did not meet the clarity and homogeneity standards required for a serum.

Table 6. Results for Batch 2 trial for hair serum (B2)

Sr. No.	Characteristics	Appearance
1.	Colour	Slightly greenish
2.	Odor	Nutty and herbal
3.	Viscosity	Slightly thicker
4.	Homogeneity	Uniform, no separation
5.	Spreadability	Slightly thicker
6.	pH	~5.5
7.	Stability	Stable, slight colour change on prolonged heating
8.	Irritation test	No irritation
9.	Hair application	Very soft, shiny hair, nourishes scalp
10.	Overall suitability	Best for dry/damaged hair

Batch 3 (B3) – Optimized Formulation:
In Batch 3, the formulation process was further refined by incorporating controlled heating (herbal infusion at regulated temperature) followed by proper filtration using muslin cloth and filter paper. The resulting serum was clear, free of suspended particles, and showed acceptable colour and odour.

Table 7. Results for Batch 3 trial for hair serum (B3)

Sr. No.	Characteristics	Appearance
1.	Colour	Light green
2.	Odor	Strong herbal aroma
3.	Viscosity	Medium, non-greasy
4.	Homogeneity	Uniform, no separation
5.	Spreadability	Moderate, absorbs well
6.	pH	~5.5
7.	Stability	Stable, slight odor change at high temperature
8.	Irritation test	No irritation
9.	Hair application	Reduces dandruff, strengthens roots, promotes growth
10.	Overall suitability	Best for dandruff and hair growth treatment

Final Optimized Formulation Results:

Table 8. Results of herbal hair serum (Final Optimized)

Sr. No.	Characteristics	Appearance
1.	Colour	Pale yellow to greenish
2.	Odour	Pleasant aromatic
3.	Physical state	Liquid
4.	pH	~5.5
5.	Viscosity	Non sticky, smooth
6.	Homogeneity	Uniform, no separation
7.	Spreadability	Easily spread on scalp without greasiness
8.	Irritation	No irritation
9.	Hair application test	Reduces hairfall and dandruff; gives shine and smoothness

The optimized Batch 3 formulation demonstrated superior physicochemical characteristics compared to Batches 1 and 2. The controlled heating method combined with proper filtration resolved the key formulation issues observed in earlier trials. The pH of ~5.5 is within the physiologically acceptable range for scalp application, minimizing potential scalp irritation. The non-greasy texture and good spreadability make the formulation suitable for regular use. Stability studies confirmed that the formulation remained unchanged under normal storage conditions, confirming its robustness for practical application.

V. CONCLUSION

The herbal hair serum formulated in the present study, using a synergistic blend of eight plant-derived oils, demonstrated promising results as a safe, effective, and natural hair care product. The formulation was optimized through iterative batch trials, with Batch 3 (B3) yielding the most satisfactory physicochemical, stability, and safety outcomes.

The serum exhibited a suitable pH (~5.5), uniform homogeneity, adequate spreadability, non-greasy texture, and freedom from irritation—all essential criteria for a cosmetically acceptable topical hair care product. The hair application test confirmed the serum's efficacy in reducing hairfall and dandruff, improving scalp health, and imparting shine and smoothness to hair.

The natural ingredients employed—particularly amla, neem, aloe vera, rosemary, and lavender oils—collectively contribute antioxidant, antimicrobial, anti-inflammatory, and hair growth-promoting activities, validating the traditional use of these herbs in Ayurvedic hair care. Vitamin E oil further enhanced the formulation's stability by preventing oxidative rancidity.

Overall, the results confirm that herbal hair serums represent a viable, sustainable alternative to synthetic hair care products. Further studies should focus on long-term clinical evaluation, optimization for specific hair types, and scale-up for commercial production.

Packaging

The optimized herbal hair serum was packaged in an amber-coloured glass container at room temperature to protect it from photodegradation, contamination, and physical deterioration, and to facilitate ease of use and distribution.

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