

From Nature to Follicle: Controlled Infusion-Based Polyherbal Hair Growth Oil — Bioactive Characterization and Dermatological Safety Profiling.

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ABSTRACT

Hair fall, hair loss, and baldness are some of the many hair problems that have increased due to hormonal imbalance, stress, air pollution, and chemical makeup products. Due to their naturalness, minimum side effects, and clinical efficacy, herbal combinations have been receiving considerable attention lately as alternative treatments. In the present study, botanical substances with proven pharmaceutical activity have been used for developing, characterising, and evaluating a polyherbal hair growth oil. In addition to the particular herbal components such as Bhringraj, Hibiscus Rosa Sinensis, Rosemary, Brahmi, and Vetiveria Zizanioides, the preparation was carried out using coconut oil, castor oil, and black seed oil as base oils. The infusion technique was adopted in the preparation of oil, and tests were carried out to determine the physical properties of the oil, its safety, and sensory characteristics. It was found out that the produced polyherbal oil was safe for external use, since it is stable, with acceptable organoleptic properties, and non-irritating. The synergistic action exhibited by the herbal compounds indicates that there could be some hair-growing properties attributed to various mechanisms, including hair follicle nourishment, improving blood flow on the scalp, antioxidants, and anti-inflammatory effects. On the whole, the research reveals that natural hair treatment using herbal drugs can serve as a sustainable alternative to artificial hair treatments, both in terms of safety and effectiveness.

Keywords: Polyherbal oil, Herbal formulation, Natural cosmetics, Follicular Drug Delivery, Controlled Infusion Technology, Bioactive Phytoconstituents.

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INTRODUCTION

Hair is one of the most important elements of human biology and cosmetics [1]. It makes the person more attractive and improves their mental state [2]. While problems such as hair thinning, hair loss, or damage may affect the individual's confidence levels and lead to distress and depression, healthy and well-cared-for hair is often associated with youth and vitality [3].

Three main stages form the clear cycle of hair growth:

- **Anagen (Growth phase)** – This period is characterised by rapid division of hair cells and formation of hair. The duration of the anagen phase determines the length of the hair strand.

- **Catagen (transition phase)** – At the conclusion of the active growth process, there is a brief period where hair growth begins to slow down, and the hair follicle begins to regress in size [4].

- **Telogen (resting phase)** – In this phase, all hair growth stops, and the old hair falls out to pave the way for new hair growth.

Disruption of any one of these phases leads to a series of conditions like alopecia and even excessive hair fall [5]. Various factors affect the regular process of hair growth, such as genetics, hormonal imbalances, poor diet, stress, pollution, and improper hair care techniques, among others [6].

1.1 PROBLEMS WITH SYNTHETIC HAIR PRODUCTS

For the purposes of enhancing the performance, stability, and sensory properties of the products, artificial compounds such as silicone, sulphate, and parabens are incorporated into the formulae of contemporary cosmetic products. While their use can provide immediate cosmetic results such as smoothness and cleansing, they may also pose some

risks to the hair and scalp when used consistently and frequently [7].

They could be:

- **Itchy scalp**– The natural protective barrier of the scalp could suffer due to excessive exposure to harmful surfactants and preservatives in the shampoos, leading to dryness, irritation, and itching of the scalp.

- **Hair fall** – Some formulations in shampoo could damage hair strands and cause follicles to weaken, eventually leading to increased hair fall and reduced hair density.

- **Allergic reactions** – In susceptible individuals, certain chemical substances could trigger hypersensitive responses, which would result in skin conditions like dermatitis or inflammation.

- **Disruption of hormones** – Questions about their safety were raised due to studies about the potential endocrine disruptor effects of some synthetic preservatives, such as parabens.

Such concerns have made people more interested in natural alternatives to traditional hair products, which are gentler and more eco-friendly [8].

1.2 IMPORTANCE OF HERBAL REMEDIES

Herbal medicine is an ancient practice used by traditional medicines such as Ayurveda, where herbs have been used in the treatment of hair growth and overall health for many years. The herbs are rich sources of bioactive phytochemicals, such as essential oils, flavonoids, alkaloids, tannins, and saponins [9]. These substances promote hair health by a variety of biological processes, such as:

- **Nourishing hair follicles** – The bioactive ingredients contain important elements such as vitamins, minerals, and essential fatty acids that ensure proper follicle functioning and strengthen hair shafts [10].

- **Better blood circulation**– Some of the plant compounds enhance scalp microcirculation, ensuring that nutrients and oxygen reach hair follicles more efficiently and stimulating their growth.

- **Oxidative stress reduction**– The antioxidants react with free radicals and protect hair follicles from any oxidative stress that might lead to hair loss or thinning.

- **Microbial infection prevention** – The anti-microbial properties of herbs help prevent dandruff and other scalp disorders by stopping germs and fungi from growing [11] [12].

1.3 RATIONALE FOR POLYHERBAL FORMULATION

Unlike the single herb formula, the polyherb formula involves combining extracts from different plants to form a therapy that brings out synergy from the combined action of different herbs for enhanced efficacy. Due to the holistic nature of this method, it is widely accepted in traditional medicine practices.

There are many advantages to polyherbal formulations in comparison with those based on single herbs.

Affecting multiple pathways – Various herbs work to tackle diverse causes for hair loss, such as poor blood flow, oxidation, hormonal imbalances, and weakened follicles.

Increase effectiveness– Increased effectiveness is often achieved due to the synergy of herbal components that increase scalp nutrition and hair growth stimulation.

Limit toxicity – Mixing different herbs in appropriate doses can limit any adverse reactions as one component can neutralize the other's toxic properties or cause irritations.

Enhance the overall performance– The use of polyherbal formulation helps to enhance strength, density, texture, and the overall health of the scalp [13].

3. MATERIALS AND METHODS

3.1 STUDY DESIGN

The present investigation aimed to develop a polyherbal hair oil containing naturally sourced ingredients with proven effectiveness for scalp well-being and hair growth by experimenting and testing their formulation. For ascertaining the efficiency and applicability of the herbal hair oil in terms of being a natural product, the experiment involved the systematic selection of herbal extracts, formulation preparation, and testing of its physicochemical, stability, safety, and sensory properties [26].

3.2 MATERIALS

3.2.1 BASE OILS

In consideration of proper delivery of active ingredients into the scalp and hair follicles, the base oils selected were made in accordance with the properties of high penetrating power, nutritious content, and ability to be combined well with herbs.

- **Coconut Oil (150 mL)** – Due to its low molecular weight, it can act effectively as a good carrier oil owing to its high penetrating abilities. Being a great base oil, it is very effective in moisturising the scalp, preventing loss of proteins in hair and enhancing its strength and shine [27].

- **Castor Oil (50 mL)** – With a high content of ricinoleic acid, it provides abundant nourishment for hair follicles, boosts blood circulation to the scalp, strengthens hair strands, and reduces split ends.

- **Black Seed Oil (*Nigella sativa*) (50 mL)** – Contains biologically active compounds such as thymoquinone, which have remarkable anti-inflammatory and antioxidant properties to protect the scalp against oxidative damage and reduce inflammation [28].

3.2.2 HERBAL INGREDIENTS

The selection of the natural ingredients was done through a careful integration of knowledge gained from scientific studies on the medicinal values of these herbs and conventional systems of knowledge, in which these herbs have been used for many years in hair treatment and scalp management. The integration of the two approaches enhances the effectiveness of the formulation by ensuring that the active ingredients used have been proven to enhance hair growth and improve the strength of hair follicles.

- **Bhringraj (*Eclipta alba*)** – This ingredient helps promote new hair growth, prevents premature graying, and increases hair density and strength. It is popularly known for its ability to rejuvenate hair health.

- **Hibiscus (*Hibiscus rosa-sinensis*)** – Full of vitamins and amino acids, this ingredient promotes prevention of hair dryness, protects from split ends, and enhances hair strength and shine.

- **Rosemary (*Rosmarinus officinalis*)** – Known for its properties in promoting an increased circulation in the scalp area, helping with nutrient delivery to hair follicles and thus promoting hair growth while reducing hair fall.
- **Brahmi (*Bacopa monnieri*)** – Known traditionally as a calming and adaptogenic plant. Brahmi strengthens hair roots and helps maintain overall good health of the scalp by making hair follicles strong and thus reducing stress-related hair fall.
- **Vetiver (*Vetiveria zizanioides*)** – Contains antiseptic properties, which keep the scalp in good condition while supporting good hair growth. It has a natural cooling effect on the scalp and thus helps reduce irritation.

3.2.3 ADDITIVES

- **Vitamin E oil** – Helps to act as an antioxidant for the protection of lipids in the scalp and hair against any oxidative stress due to the presence of free radicals. Apart from these, it helps in improving the overall health of follicles and increasing the scalp circulation, along with extending the shelf life of the formula by preventing oxidation in the oils, thus providing healthy and glossy hair.
- **Essential oil (Rosemary)** – Works as a natural fragrance component as well as a medicinal one. Not only does it have anti-bacterial properties, but it also helps in revitalisation of the scalp, promoting blood circulation in the scalp as well as hair follicles, thus decreasing hair thinning.

3.4 METHOD OF PREPARATION

3.4.1 PREPARATION OF HERBAL EXTRACT

Collection and Cleaning of Herbal Materials – To ensure the quality of the raw herbal medicines, the selected dried herb ingredients were collected and washed to eliminate any dirt, dust, and unwanted impurities.

Shade Drying Process – After cleaning the herbs, they were subjected to controlled shade drying to maintain their biological properties since some phytochemicals are heat and light-sensitive.

Size Reduction (Grinding) – To increase the surface area and facilitate extraction during formulation, the shade-dried herbs were ground into coarse powder through mechanical grinding.

3.4.2 INFUSION PROCESS

Formulation of the Base Oils – The base oils of black seed oil, castor oil, and coconut oil were measured accurately and introduced to a sterilised beaker to provide the base for the formulation process.

Addition of Herbal Powdered Components – To ensure uniform mixing, the powdered herbal substances were gradually added to the oils and kept stirring all the while.

Heating Process – To enable the extraction of biological components of the herbal powder into the oil phase, the oils were heated at 60–70°C for two to three hours.

Temperature Control – The therapeutic properties of the formulation were maintained through precise control of the heating temperature so that the heat-sensitive components would not be destroyed.

Process of Cooling – To stabilise the formulation before further processing, it was cooled at room temperature after the heating process was completed.

3.4.3 FILTRATION

Alteration of the Herbal Oil Mixtures – The cooling process was completed to ensure that the herbal oil mixture was crystal clear, which required the use of a muslin cloth for filtration.

Pressing of Residue – The remaining herb remains were squeezed to extract all the oils that may still be present to improve the efficiency of extraction and increase the output.

Collection and Storage – The extracted herbal oils had to be collected and stored properly to prevent contamination, oxidation, and evaporation.

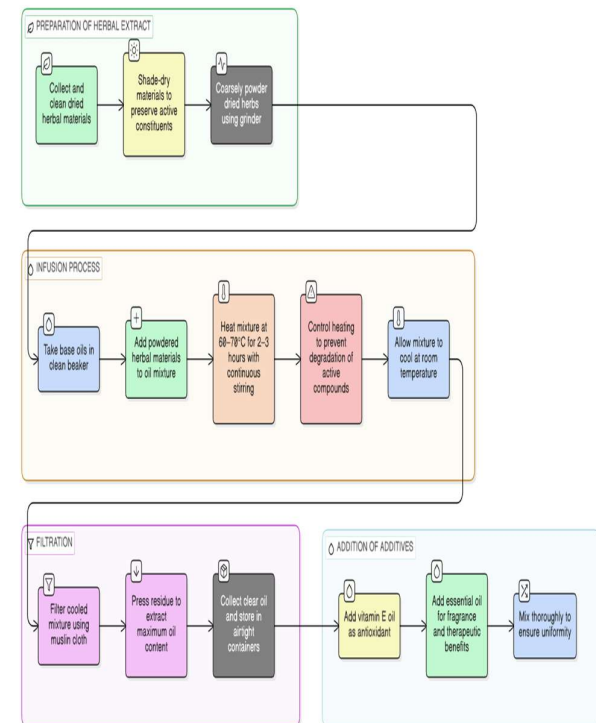
3.4.4 ADDITION OF ADDITIVES

Addition of Vitamin E Oil – Vitamin E oil has been used due to its antioxidant properties, which help in preventing oils from being oxidised and thus extending the shelf life of the product.

Addition of Essential Oil – Essential oil helps in providing additional therapeutic qualities, such as improved circulation and antibacterial properties, apart from adding fragrance.

Homogenization of the Formulation – To ensure proper distribution of each component in the mixture, it has been stirred well to form a homogeneous polyherbal hair oil formulation.

Fig.1: Methods of preparation of the herbal hair oil



3.5 FORMULATION TABLE

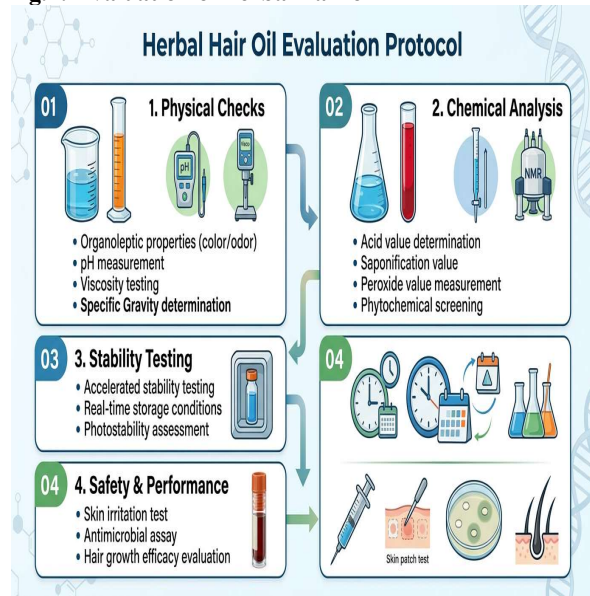
Ingredient	Quantity	Function
Coconut Oil	150 mL	Base oil, moisturiser
Castor Oil	50 mL	Hair thickening

Ingredient	Quantity	Function
Black Seed Oil	50 mL	Antioxidant
Bhringraj	q.s.	Hair growth
Hibiscus	q.s.	Hair strengthening
Rosemary	q.s.	Circulation enhancer
Brahmi	q.s.	Stress relief
Vetiver	q.s.	Cooling agent
Vitamin E	Few drops	Antioxidant

Table. 1: Formulation of herbal hair growth oil

3.6 EVALUATION OF HERBAL HAIR OIL

Fig.2: Evaluation of herbal hair oil



3.6.1 ORGANOLEPTIC EVALUATION

Colour – Colour of the hair oil obtained from herbs was tested to ensure proper uniformity and the absence of any discoloured elements to confirm that proper extraction and mixing of the herbs had taken place.

Odour – odour testing was done to ensure that herbs used together with the essential oils have created a pleasant odour without producing any kind of rancidity or foul odour.

Texture – To ensure smoothness and ease of application on the scalp and hair, texture testing was carried out.

3.6.2 PHYSICOCHEMICAL EVALUATION

A. PH DETERMINATION

The calibrated digital pH meter was employed in measuring the pH level of the herbal hair oil that was made to ensure that the measurement was accurate and reliable. This aspect is very important in ensuring that the formulation does not have any effects on the pH levels of the scalp.

B. VISCOSITY

The viscosity of the prepared herbal hair oil was evaluated using a viscometer. The importance of this parameter is that it helps in determining how well the hair oil can be accepted by consumers, spread through the scalp, and applied easily. The viscosity of the formulated hair oil was determined by using a viscometer, as a means of determining the nature of

flow of the product. This test is important in understanding the flow behaviour of the formulation, which directly affects its spreadability on the scalp.

C. SPECIFIC GRAVITY

The specific gravity of the herbal hair oil that was prepared was determined using a gravity bottle test. This determination is important because it helps to determine the density of the mixture relative to water.

3.6.3 STABILITY STUDIES

To analyse the physical stability of the developed herbal hair oil throughout time, samples were kept at different temperatures, such as room temperature and higher temperatures. Samples were frequently analysed for any changes in significant properties, such as colour, phase separation, and odour.

- **Colour change** – to identify any discolouration due to oxidation of oils or spoilage of the herbal constituents.
- **Phase separation** – to investigate the physical stability and consistency of the formulation under different storage conditions.
- **Odour changes** – to analyse any foul or altered odour due to the breakdown of the product.

3.6.4 PATCH TEST (SAFETY STUDY)

Sample Application– To determine the safety of the herbal hair oil on the skin, a small quantity was applied to a limited section of the skin surface.

Skin Reaction Observation Time – To detect any instant or delayed skin reaction caused by the oil, the site of application was observed for a whole day.

Skin Reaction Assessment – To ensure that the preparation is free from irritancy and safe for skin application, the area was examined for any sign of irritation or adverse effect, such as redness or itching.

3.6.5 SENSORY EVALUATION

Parameters Evaluated:

- **Spreadability** – In order to ensure that the herb hair oil can be easily spread over the head for adequate coverage without using too much oil, the spreadability factor was tested.
- **Absorption** – To test the effectiveness of the oil and its non-greasy nature after being applied, the absorption process was also examined.
- **Greasiness** – To improve user comfort and acceptance, the residual oily feel on the scalp and hair was evaluated to make sure the formulation is either non-greasy or very greasy.
- **Fragrance** – To provide users with a satisfactory sensory experience, the formulation's scent was assessed for its pleasantness, natural appeal, and stability over time.

3.6.6 MICROBIAL TESTING

• **Total Microbial Count** -The prepared hair oil was examined for its total microorganism content in order to ensure that the viable microorganism count was within an acceptable range.

• **Absence of Pathogenic Organisms** – To establish the safety and hygiene of the formulation and ensure that it does not pose any infection risk when applied on the scalp, it was

analysed for the absence of any hazardous microorganisms, such as bacteria and fungi [29].

3.7 Statistical Analysis

The measure of central tendency and dispersion was calculated by using mean±standard deviation (SD). For the estimation of the efficacy, reliability, and validity of the prepared herbal hair oil, the results were statistically analysed through the application of descriptive statistics. Such an approach facilitated objective analysis of the experimentally obtained data and helped assess the properties of the formulation [30].

4. RESULTS

The assessment of the quality, safety, and efficacy of this polyherbal hair oil was done using several criteria. Organoleptic properties such as color, odor, and consistency, physicochemical properties such as pH, viscosity, and density, stability testing under different storage conditions, and evaluation of the safety of the product using skin irritation tests were some of the parameters tested. All these measures were aimed at ensuring that the formulation was potentially effective as an herbal hair treatment formula.

4.1 ORGANOLEPTIC PROPERTIES

Parameter	Observation
Colour	Amber to dark brown
Odour	Pleasant, aromatic
Texture	Smooth, non-greasy
Appearance	Clear, free from particles

Table 2: Organoleptic characteristics of herbal oil

Interpretation:

The preparation had good aesthetic attributes, such as a good appearance, a pleasant fragrance, and a proper feel, which make it a highly acceptable one to consumers. This implies that this product has good sensory properties and hence can be used regularly in cosmetics.

4.2 PHYSICOCHEMICAL EVALUATION

Parameter	Result
pH	5.5 – 6.5
Viscosity	Moderate
Specific Gravity	~0.91
Acid Value	Within acceptable limits

Table 3: Physicochemical Evaluation of herbal oil

Interpretation:

- **pH compatibility** – The formulation was observed to have a pH value very close to that of the natural pH of the human scalp, suggesting good compatibility and a lower chance of skin irritation.
- **Viscosity characteristics** – The formulation had moderate viscosity, which is an important factor for smooth and even application to the scalp.

4.3 STABILITY STUDY

Condition	Observation
Room temperature	Stable
Elevated temperature	No phase separation
Light exposure	No significant change

Table.4: Stability tests for herbal oil

Interpretation:

Good stability was observed during the storage of the prepared product, as there were no changes in the physical and organoleptic properties of the drug. This implies that the shelf-life is satisfactory, and the product can be stored over a long period without a reduction in its effectiveness.

4.4 PATCH TEST

Parameter	Result
Irritation	None
Redness	Absent
Itching	Absent

Table 5: Hypersensitivity tests for hair oil

Interpretation:

As there were no signs of any skin irritation, redness, itching, or other adverse effects during the testing period, the preparation was considered safe for application to the skin. This indicates that the product has adequate compatibility with the skin and can be safely applied to the skin and hair.

4.5 SENSORY EVALUATION

Parameter	Rating
Spreadability	Excellent
Absorption	Good
Greasiness	Low
Fragrance	Pleasant

Table. 6: Physical evaluation of herbal oil

5. DISCUSSION

This particular study has successfully made an innovative polyherbal hair oil by amalgamating some ancient medicines that possess curative values which have been confirmed through scientific methods. The concoction provides a natural and holistic solution for hair care due to the inclusion of various herbs that are known to strengthen and promote hair growth.

5.1 Significance of Herbal Ingredients

Different advantages were provided by each herb that made up the mixture:

- Bhringraj ensures continued hair growth as it stimulates the hair follicles and prolongs the hair's anagen phase (the hair's growing phase).
- The integrity of the hair shaft is supported through hibiscus, which strengthens the hair and reduces the risk of breakage.
- Rosemary can be useful in preventing hair loss from androgenic activity due to DHT and improves blood circulation in the scalp, providing sufficient nutrition to hair follicles.
- The soothing and adaptogenic nature of brahmi helps prevent hair loss from stress and increases overall scalp and hair health.
- Due to its calming and antibacterial properties, vetiver is effective at maintaining cleanliness of the scalp and reducing inflammation [31].

5.2 SYNERGISTIC EFFECT

The synergy from using various plants in the preparation resulted in:

- **Nutrient delivery improvement** - Increased delivery of nutrients into the scalp and hair follicles through enhanced penetration of active chemicals.

● **Scalp improvement** – The combined effects of antibacterial, anti-inflammatory, and antioxidant components-maintained scalp health conducive to hair growth.

● **Multiple targets** – Several physiological mechanisms, such as stimulation of follicles, increased blood flow, stress relief, and oxidative stress control, were influenced by various herbal ingredients.

One advantage that can be drawn from polyherbal preparations is synergy. This gives the most comprehensive approach to hair care compared to monotherapy [32].

Fig.3: Advantages of combination of herbs in herbal hair oil

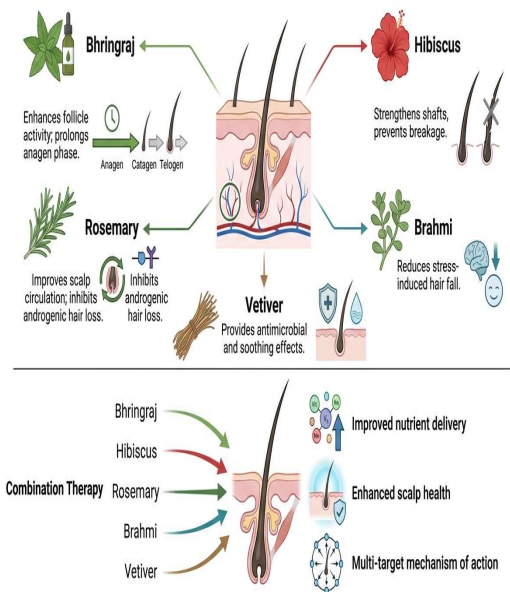


Table. 7: Comparison of other herbal hair growth oil

5.4 MECHANISM OF ACTION

This is achieved using various modes of operation within the product:

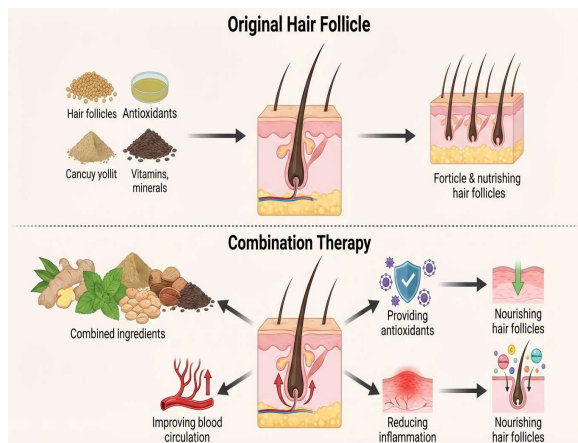
● **Improving blood circulation** – enhances the microcirculation within the scalp and ensures that the hair follicles receive oxygen and essential nutrients for proper hair growth.

● **Hair antioxidant supply** – slows hair thinning and hair loss as antioxidants counteract free radicals and protect the skin of the scalp and hair follicles from oxidative damage.

● **Inflammation reduction** – helps reduce irritation and inflammation of the scalp and encourages hair growth.

● **Hair follicle nutrition** – helps provide fatty acids, vitamins, and phytochemicals to improve hair strength and quality [33].

Fig.4: Mechanism of action of herbal hair growth oil



6. CONCLUSION

Through the utilisation of natural products with documented medicinal properties, the current research has successfully focused on the formulation and evaluation of a hair growth-enhancing oil. The formulation involves the combination of base oils and herbal extracts such as *Eclipta alba*, *Hibiscus rosa-sinensis*, *Rosmarinus officinalis*, *Bacopa monnieri*, and *Vetiveriazanioides*, all of which provide distinct benefits to hair health.

The following characteristics were observed in the prepared formulation:

● **Physicochemical characteristics** – The formulation exhibited good physical and chemical attributes based on its pH value, viscosity, and specific gravity.

● **Stability during storage** – The formulation showed stability based on the absence of any changes in appearance, odour, or phase separation.

● **No irritation observed through patch test** – The safety of the application of the product topically without causing any irritation was proven to be true.

● **Good sensory properties** – The good texture, pleasant odour, and spreadability contributed to the acceptance of the formula by the consumers.

In summary, the herbal oil possesses promising potential to improve hair quality by fortifying hair follicles, reducing hair fall, and promoting hair growth via different methods such as improved blood flow, anti-inflammatory action, antioxidant effect, and nourishment of the scalp. This experiment supports the notion that polyherbal mixtures, which offer holistic benefits with minimum side effects, serve as a better and safer alternative to artificial hair-care products. Further clinical studies involving larger sample sizes should be conducted to validate the efficacy of this mixture and determine long-term treatment outcomes..

REFERENCE

1. Singh C, Yashwant, Gupta AK, Garg V. Formulation development and evaluation of divalproex sodium extended-release tablets. *International Journal of Drug Delivery Technology*. 2022;12(4):1769-1773. doi:10.25258/ijddt.12.4.46
2. Shukla P, Joshi D, Kumar Y, Chaturvedi M, Goswami N. Herbal hair oil for enhancement of hair growth: formulation and evaluation. *International Journal*

- of Pharmaceutical Research and Development. 2026;8(3):12–14. doi:10.33545/26646862.2026.v8.i3a.284
3. Zgonc Škulj A, Poljšak N, Kočevar Glavač N, Kreft S. Herbal preparations for the treatment of hair loss. *Archives of Dermatological Research*. 2019;312(6):395–406. doi:10.1007/s00403-019-01943-2
4. Bin Rubaian N, Alzamami H, Amir B. An overview of commonly used natural alternatives for the treatment of androgenetic alopecia, with special emphasis on rosemary oil. *Clinical, Cosmetic and Investigational Dermatology*. 2024;17:2495–2503. doi:10.2147/CCID.S473594
5. Askar MA, Thangiam NM, Kumar A. A review on pharmacological importance of polyherbal formulation. *Research Journal of Pharmacy and Technology*. 2025;18(4):1925–1930. doi:10.52711/0974-360X.2025.00275
6. Zgonc Škulj A, Poljšak N, Kočevar Glavač N, Kreft S. Herbal preparations for the treatment of hair loss. *Molecules*. 2020;25(3):678. doi:10.3390/molecules25030678
7. Auguste D, Miller SL. Volatile organic compound emissions from heated synthetic hair: a pilot study. *Environmental Health Insights*. 2020;14:117863021989087. doi:10.1177/1178630219890870
8. Wilson N, Thomson A, Moore-Millar K, Ijomah W. Capturing the life cycle of false hair products to identify opportunities for remanufacture. *Journal of Remanufacturing*. 2019;9(3):235–256. doi:10.1007/s13243-019-0067-0
9. Aslam MS, Kim YJ. Herbal medicine in the modern age: the era of personalized precision. *Journal of Integrative Medicine*. 2025;23(8):100705. doi:10.1016/j.joim.2025.08.005
10. Park S, Lee J. Modulation of hair growth promoting effect by natural products. *Pharmaceutics*. 2021;13(12):2163. doi:10.3390/pharmaceutics13122163
11. Kerk SK, Lai HY, Sze SK, Ng KW, Schmidtchen A, Adav SS. Bacteria display differential growth and adhesion characteristics on human hair shafts. *Frontiers in Microbiology*. 2018;9:2145. doi:10.3389/fmicb.2018.02145
12. Constantinou A, Kanti V, Polak-Witka K, Blume-Peytavi U, Spyrou GM, Vogt A. The potential relevance of the microbiome to hair physiology and regeneration: the emerging role of metagenomics. *Biomedicines*. 2021;9(3):236. doi:10.3390/biomedicines9030236
13. Populwar V, Mehta P, Shinde N, Dhebe D. Formulation and evaluation of polyherbal hair gel. *Research Journal of Pharmacy and Technology*. 2024;17(6):2618–2622. doi:10.52711/0974-360X.2024.00409
14. Mysore V, Arghya A. Hair oils: indigenous knowledge revisited. *International Journal of Trichology*. 2022;14(3):84–90. doi:10.4103/ijt.ijt_24_22
15. Pan X, Yu R, Wu J, Li W, Huang R, Huang W, et al. Technological advances in anti-hair loss and hair regrowth cosmeceuticals: mechanistic breakthroughs and industrial prospects driven by multidisciplinary collaborative innovation. *Aesthetic Plastic Surgery*. 2025. doi:10.1007/s00266-025-04172-3
16. Herdiana Y. Gray hair: from preventive to treatment. *Clinical, Cosmetic and Investigational Dermatology*. 2025;18:1475–1494. doi:10.2147/CCID.S515087
17. Balkrishna A, Singh S, Mishra S, Rana M, Mishra RK, Rajput SK, et al. Ayurvedic approaches to managing premature greying of hair: a comprehensive review. *Current Cosmetic Science*. 2024;4(4):266–279. doi:10.2174/0126667797337717241212051309
18. Putra IB, Jusuf NK, Sumantri IB. The potency of *Hibiscus rosa-sinensis* Linn. leaves ethanol extract as hair growth. *Open Access Macedonian Journal of Medical Sciences*. 2020;8(A):89–92. doi:10.3889/oamjms.2020.3803
19. Pohane DV, Bhat A, Gaikwad SS, Gaikwad SN, Patil ML, Dighade NR. Formulation and evaluation of hibiscus hair oil for hair rejuvenation. *Research Journal of Pharmacy and Technology*. 2025;18(6):2454–2458. doi:10.52711/0974-360X.2025.00359
20. Alawadh RM, Alsheriai SN, Al-Husain KM, Albreiki SH, Al Drees EA, Alkhudair DH, et al. Unlocking the potential of rosemary in alopecia: a narrative review of evidence on mechanism, applications and challenges. *Journal of Advanced Trends in Medical Research*. 2025;2(4):649–653. doi:10.4103/atmr.atmr_15_25
21. Eid AM, Elmarzugi NA, Abu Ayyash LM, Sawafita MN, Daana HI. A review on the cosmeceutical and external applications of *Nigella sativa*. *Journal of Tropical Medicine*. 2017;2017:1–7. doi:10.1155/2017/7092518
22. Maxhuni Q, Ferizi R, Ramadan M. Black seeds (*Nigella sativa*) medical application and pharmaceutical perspectives. *Journal of Pharmacy and Bioallied Sciences*. 2023;15(2):63–63. doi:10.4103/jpbs.jpbs_364_22
23. Zirmire RK, Saha D, Dey R, Tanimu H, Zaarour R, Bird D, et al. *Bacopa monnieri* phytochemicals regulate fibroblast cell migration via modulation of focal adhesions. *iScience*. 2024;27(4):109489. doi:10.1016/j.isci.2024.109489
24. De Tollenaere M, Chapuis E, Lapierre L, Bracq M, Hubert J, Lambert C, et al. Overall renewal of skin lipids with vetiver extract for a complete anti-ageing strategy. *International Journal of Cosmetic Science*. 2020;43(2):165–180. doi:10.1111/ics.12674
25. Gunasekar CJ, Majdalawieh AF, Abu-Yousef IA, Refaai A. Pharmacological and therapeutic potential of *Chrysopogon zizanioides* (vetiver): a comprehensive review of its medicinal applications and future prospects. *Biomolecules*. 2025;15(9):1312. doi:10.3390/biom15091312
26. Haq N, Shahid M, Alaofi AL, Ahmad ZH, Alrarrayes YF, Alsarra IA, et al. Evaluation of the physicochemical and antimicrobial properties of nanoemulsion-based polyherbal mouthwash. *ACS Omega*. 2023;8(44):41755–41764. doi:10.1021/acsomega.3c05562
27. Maghraby YR, Ibrahim AH, El-Shabasy RM, Azzazy HMES. Overview of nanocosmetics with emphasis

- on those incorporating natural extracts. ACS Omega. 2024. doi:10.1021/acsomega.4c05561
28. Rahim MA, Shoukat A, Khalid W, Ejaz A, Itrat N, Majeed I, et al. A narrative review on various oil extraction methods, encapsulation processes, fatty acid profiles, oxidative stability, and medicinal properties of black seed (*Nigella sativa*). *Foods*. 2022;11(18):2826. doi:10.3390/foods11182826
29. Sharma A, Sharma L. Antimicrobial and anti-infective potential of herbal creams in dermatology: efficacy, safety, and challenges in skin infection management. *Infection and Drug Resistance*. 2025;18:6289–6311. doi:10.2147/IDR.S507214
30. Begum AN, Sandhya S, Anoop Kumar N, Syed Shahid Ali. Evaluation of herbal hair lotion loaded with rosemary for possible hair growth in C57BL/6 mice. *Journal of Pharmaceutical Negative Results*. 2023;14(1):60–66. doi:10.47750/pnr.2023.14.01.009
31. Uronnachi E, Atuegwu C, Umeyor C, Nwakile C, Obasi J, Ikeotuonye C, et al. Formulation and evaluation of hair growth enhancing effects of oleogels made from rosemary and cedar wood oils. *Scientific African*. 2022;16:e01223. doi:10.1016/j.sciaf.2022.e01223
32. Muangsanguan A, Ruksiriwanich W, Linsaenkart P, Jantrawut P, Rachtanapun P, Jantanasakulwong K, et al. Synergistic phytochemical and pharmacological actions of Hair Rise™ microemulsion: a novel herbal formulation for androgenetic alopecia and hair growth stimulation. *Plants*. 2024;13(19):2802. doi:10.3390/plants13192802
33. Kesika P, Sivamaruthi BS, Thangaleela S, Bharathi M, Chaiyasut C. Role and mechanisms of phytochemicals in hair growth and health. *Pharmaceuticals*. 2023;16(2):206. doi:10.3390/ph16020206
34. Parasuraman S, Thing GS, Dhanaraj SA. Polyherbal formulation: concept of Ayurveda. *Pharmacognosy Reviews*. 2014;8(16):73–80. doi:10.4103/0973-7847.134229.
35. Tiwari G, Tiwari R. Assessment of nutraceutical potential of herbs for promoting hair growth: formulation considerations of herbal hair oil. *The Open Dermatology Journal*. 2021;15(1):78–83. doi:10.2174/1874372202115010078