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HERBAL HAIR OILS: TRADITIONAL FORMULATIONS, MEDICINAL PLANTS, MECHANISMS, AND SCIENTIFIC VALIDATION FOR HAIR HEALTH AND GROWTH PROMOTION

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ABSTRACT

Hair and scalp disorders such as hair fall, dandruff, premature greying, and alopecia are increasingly prevalent due to lifestyle changes, environmental pollution, nutritional deficiencies, and excessive use of synthetic cosmetic products. Herbal hair oils have been traditionally used in various systems of medicine, particularly Ayurveda, as safe and effective remedies for maintaining hair health and promoting hair growth. These formulations utilize medicinal plant extracts incorporated into suitable carrier oils to deliver bioactive phytoconstituents directly to the scalp and hair follicles.The present review provides a comprehensive overview of herbal hair oil formulations, emphasizing medicinal plants used, carrier oils, mechanisms of action, methods of preparation, formulation development, evaluation parameters, and scientific validation through preclinical and clinical studies. Key herbs such as *Eclipta alba*, *Phyllanthus emblica*, *Hibiscus rosa-sinensis*, *Azadirachta indica*, and *Bacopa monnieri* exhibit hair growth–promoting, antioxidant, anti-inflammatory, and antimicrobial properties that contribute to improved follicular function and scalp health. Carrier oils including coconut, sesame, almond, and castor oil enhance penetration, stability, and therapeutic efficacy of herbal constituents. Traditional preparation methods like Taila Kalpana, infusion, and decoction ensure effective extraction of active compounds, while modern pharmaceutical approaches facilitate standardization and quality control. Evaluation parameters such as physicochemical analysis, microbial testing, stability studies, and dermal

safety assessments are crucial for ensuring product quality and consumer safety. Preclinical studies demonstrate stimulation of hair follicles and prolongation of the anagen phase, whereas clinical evidence supports the role of herbal hair oils in reducing hair fall, managing dandruff, and improving hair texture with minimal adverse effects.

In conclusion, herbal hair oils represent a holistic, safe, and effective approach to hair care. Integration of traditional knowledge with modern scientific research and standardized formulation practices can further enhance their therapeutic potential and acceptance in contemporary cosmetic and dermatological applications.

KEYWORDS: Herbal hair oil; Ayurveda; Eclipta alba; Phyllanthus emblica; Hair growth; Anagen phase; Taila Kalpana; Antioxidant.

INTRODUCTION

Hair is an essential component of human identity and appearance, contributing significantly to self-esteem, social communication, and psychological well-being. Structurally, hair originates from hair follicles, which are highly active mini-organs undergoing continuous cycles of growth and regression throughout life. Any disturbance in this tightly regulated cycle can lead to hair disorders such as alopecia, dandruff, scalp inflammation, dryness, brittleness, and premature greying.[1-2] In recent decades, the prevalence of hair and scalp disorders has increased considerably across all age groups, largely due to rapid urbanization, exposure to environmental pollutants, poor dietary habits, hormonal imbalances, chronic stress, and genetic susceptibility.[3]

Alopecia, in particular, represents one of the most common dermatological concerns globally and may arise from androgenic, autoimmune, nutritional, or idiopathic causes. Although not life-threatening, hair loss has profound psychosocial implications, often leading to anxiety, reduced self-confidence, and emotional distress.[4] Conventional therapeutic approaches for hair loss primarily include topical minoxidil and oral finasteride. While these agents have demonstrated clinical efficacy, their prolonged use is frequently associated with undesirable effects such as scalp irritation, contact dermatitis, sexual dysfunction, hormonal imbalance, and recurrence of hair fall after treatment cessation.[5-6] These limitations have highlighted the need for alternative strategies that are both effective and safe for long-term use.

Herbal hair oils have emerged as promising alternatives due to their natural origin, multifaceted therapeutic activity, and historical acceptance. The use of plant-based oils for hair care dates back thousands of years and is well documented in traditional systems of medicine such as Ayurveda, Siddha, Unani, and traditional Chinese medicine.[7] Ancient Ayurvedic texts including *Charaka Samhita* and *Sushruta Samhita* describe various medicated oils (*Taila Kalpana*) prepared using herbs like *Eclipta alba* (bhringraj), *Phyllanthus emblica* (amla), *Bacopa monnieri* (brahmi), and *Azadirachta indica* (neem) for maintaining scalp health and preventing hair disorders.[8] Regular application of these oils, often accompanied by scalp massage (*Shiro Abhyanga*), is believed to enhance blood circulation, nourish hair roots, and balance the body's doshas.

Herbal hair oils are typically formulated by incorporating medicinal plant extracts or decoctions into suitable carrier oils such as coconut oil, sesame oil, castor oil, almond oil, or olive oil. These carrier oils not only act as vehicles for the delivery of active phytoconstituents but also possess intrinsic therapeutic properties, including emollient, moisturizing, and antimicrobial effects.[9] The bioactivity of herbal hair oils is attributed to a diverse range of phytochemicals such as flavonoids, alkaloids, tannins, saponins, terpenoids, vitamins, and essential fatty acids, which collectively contribute to hair growth promotion, follicular nourishment, antioxidant protection, and antimicrobial action.[10]

Scientific investigations over the past two decades have increasingly focused on validating the traditional claims associated with herbal hair oils. Experimental studies suggest that certain herbal formulations can stimulate hair follicle proliferation, prolong the anagen phase of the hair cycle, reduce inflammation, and inhibit microbial growth on the scalp.[11] Clinical studies on polyherbal formulations have reported improvements in hair density, hair thickness, reduction in dandruff, and enhancement of overall hair quality, sometimes showing comparable efficacy to synthetic agents in mild to moderate cases of hair loss.[12] Additionally, herbal hair oils are generally associated with lower incidence of adverse reactions, making them suitable for prolonged use.

Despite their widespread use and commercial availability, the development of herbal hair oils faces several challenges, including lack of standardization, variability in raw material quality, insufficient clinical data, and inconsistent regulatory frameworks.[13] Therefore, a comprehensive scientific evaluation of herbal hair oils encompassing formulation strategies, quality control parameters, pharmacological efficacy, and safety assessment is essential. This

review aims to provide an in-depth overview of herbal hair oils, integrating traditional knowledge with modern scientific evidence to highlight their therapeutic potential, limitations, and future prospects in hair and scalp care.

In recent years, there has been a marked increase in consumer inclination toward herbal and natural hair care products, largely due to heightened awareness regarding the potential adverse effects of synthetic chemicals present in conventional cosmetics. Ingredients such as parabens, sulfates, synthetic fragrances, and preservatives have been associated with scalp irritation, allergic reactions, disruption of the skin barrier, and long-term dermatological concerns.[14] This growing concern has significantly accelerated the demand for herbal hair oils, which are perceived as safer, eco-friendly, and more compatible with long-term use.

Herbal hair oils are generally formulated as polyherbal preparations, combining multiple medicinal plants to achieve synergistic therapeutic effects. Unlike synthetic agents that act on a single molecular target, herbal hair oils exert their effects through multiple biological pathways, including stimulation of hair follicle activity, regulation of sebum secretion, reduction of oxidative stress, and control of microbial growth on the scalp.[15] This multitargeted mechanism is particularly advantageous in the management of complex hair disorders, where factors such as inflammation, infection, nutritional deficiency, and hormonal imbalance coexist [16] Phytochemical studies have demonstrated that medicinal plants used in herbal hair oil formulations are rich sources of bioactive compounds such as flavonoids, phenolic acids, alkaloids, terpenoids, saponins, and essential fatty acids. These compounds play a crucial role in protecting hair follicle cells from oxidative damage, enhancing dermal papilla cell proliferation, and modulating growth factor expression involved in hair regeneration.[17] Antioxidants present in herbs like amla and hibiscus help neutralize free radicals, thereby delaying follicular aging and preventing premature greying[18] Carrier oils used in herbal hair oils, such as coconut oil, sesame oil, castor oil, and almond oil, contribute significantly to the overall efficacy of the formulation. These oils not only facilitate the extraction and delivery of herbal constituents but also improve penetration through the stratum corneum and hair follicle openings.[19] Studies have shown that coconut oil, due to its low molecular weight and high affinity for hair proteins, can penetrate the hair shaft and reduce protein loss, thereby strengthening hair and preventing damage.[20]

Advances in experimental dermatology have further supported the traditional claims associated with herbal hair oils. In vitro and in vivo studies suggest that certain herbal

extracts can promote the transition of hair follicles from the telogen phase to the anagen phase by increasing cellular proliferation and enhancing local blood circulation[21] Additionally, antimicrobial studies indicate that herbs such as neem, tulsi, and tea tree oil effectively inhibit dandruff-causing microorganisms, including *Malassezia* species, thereby improving scalp health and reducing hair fall associated with seborrheic dermatitis.[22]

Despite their widespread traditional use and commercial popularity, the scientific development of herbal hair oils is hindered by challenges related to standardization, quality control, and regulatory compliance. Variability in plant species, geographical origin, harvesting conditions, and extraction techniques can lead to significant differences in the quality and efficacy of herbal formulations.[23] Furthermore, the absence of robust clinical trials and harmonized regulatory guidelines limits the acceptance of herbal hair oils in evidence-based dermatological practice.[24] Addressing these limitations through systematic research and standardized evaluation protocols is essential for ensuring product quality, safety, and therapeutic reliability.

Hair Structure and Hair Growth Cycle

Hair is a complex keratinized structure derived from the epidermis and is composed of both visible and invisible components. Anatomically, hair consists of the **hair shaft**, which projects above the skin surface, and the **hair follicle**, which is embedded within the dermis and hypodermis. The hair follicle is a dynamic mini-organ that plays a central role in hair growth, pigmentation, and cycling, and is highly responsive to hormonal, nutritional, and environmental influences.[25]

Structure of the Hair Shaft

The hair shaft is composed of three concentric layers: the **cuticle**, **cortex**, and **medulla**. The cuticle is the outermost protective layer consisting of overlapping keratinized cells that shield the inner structures from physical and chemical damage. Damage to the cuticle results in hair roughness, breakage, and loss of shine. The cortex constitutes the bulk of the hair shaft and is responsible for mechanical strength, elasticity, and color, as it contains melanin granules and keratin fibers. The medulla, which may be absent in fine hair, forms the innermost core and contributes minimally to hair strength.[26]

Herbal hair oils primarily act on the cuticle and cortex by forming a protective film over the hair shaft, reducing friction, preventing moisture loss, and minimizing protein degradation.

Oils such as coconut and sesame oil have been shown to penetrate the hair shaft and bind to keratin, thereby improving tensile strength and reducing hair damage.[27]

Structure of the Hair Follicle

The hair follicle consists of several components, including the hair bulb**,** dermal papilla**,** outer root sheath**,** inner root sheath, and sebaceous gland**.** The dermal papilla is a highly vascularized structure that regulates hair growth by supplying nutrients and growth factors to the follicular matrix cells. Any impairment in dermal papilla function can disrupt hair growth and lead to hair loss.[28]

Sebaceous glands associated with hair follicles secrete sebum, which lubricates the scalp and hair shaft. Herbal hair oils help supplement natural sebum, especially in individuals with dry scalp, and maintain optimal scalp hydration and barrier function.[29]

Hair Growth Cycle

Hair growth occurs in a cyclical manner and consists of three distinct phases: anagen (growth phase)**,** catagen (regression phase), and telogen (resting phase)**.** The anagen phase is characterized by active cell division in the hair matrix and may last from 2 to 7 years, depending on genetic and hormonal factors. Approximately 85–90% of scalp hair is in the anagen phase at any given time.[30]

The catagen phase is a short transitional phase lasting about 2–3 weeks, during which follicular activity decreases and the hair follicle undergoes programmed regression. This is followed by the telogen phase, which lasts approximately 2–3 months, during which the hair remains dormant before being shed. Excessive conversion of anagen follicles into the telogen phase is a hallmark of many hair loss disorders, including telogen effluvium and androgenetic alopecia.[31]

Role of Herbal Hair Oils in Hair Cycle Regulation

Herbal hair oils are believed to exert a positive influence on the hair growth cycle by prolonging the anagen phase and delaying premature entry into the telogen phase. Experimental studies suggest that certain herbal extracts stimulate proliferation of dermal papilla cells, enhance microcirculation around hair follicles, and increase expression of growth-promoting factors such as insulin-like growth factor-1 (IGF-1) and vascular endothelial growth factor (VEGF).[32]

Additionally, regular application and massage of herbal hair oils reduce scalp tension, improve follicular oxygenation, and facilitate removal of follicular blockages, thereby creating a favorable environment for hair growth. The combined mechanical and pharmacological effects of herbal hair oil massage contribute significantly to improved hair density and scalp health.[33]

Mechanism of Action of Herbal Hair Oils

Herbal hair oils exert their beneficial effects on hair and scalp through a multifactorial mechanism involving biological, physicochemical, and pharmacological actions. Unlike synthetic agents that typically act on a single target, herbal hair oils influence multiple pathways simultaneously, thereby providing comprehensive hair care and therapeutic benefits. The combined action of herbal bioactive compounds and carrier oils plays a crucial role in improving hair follicle function, scalp health, and hair shaft integrity.[34]

1. Stimulation of Hair Follicle Activity

One of the primary mechanisms of herbal hair oils is stimulation of hair follicle activity, particularly the dermal papilla cells that regulate hair growth. Bioactive phytoconstituents such as flavonoids, alkaloids, and terpenoids present in herbs like bhringraj, amla, and hibiscus have been shown to enhance cellular proliferation and metabolic activity of hair follicle cells.[35] These compounds promote the transition of hair follicles from the telogen (resting) phase to the anagen (growth) phase, thereby increasing hair density and reducing hair fall.

Several experimental studies indicate that herbal extracts upregulate growth factors such as vascular endothelial growth factor (VEGF), insulin-like growth factor-1 (IGF-1), and fibroblast growth factor (FGF), which are essential for follicular angiogenesis and nutrient supply[36] Improved blood flow and oxygenation around hair follicles create a favorable environment for sustained hair growth.

2. Improvement of Scalp Microcirculation

Scalp massage with herbal hair oils enhances local blood circulation, which facilitates the delivery of oxygen, nutrients, and bioactive compounds to hair follicles. Improved microcirculation also aids in the removal of metabolic waste products, thereby preventing follicular miniaturization and dysfunction.[37] Oils such as sesame and castor oil possess

warming properties that further stimulate capillary dilation and enhance transdermal absorption of herbal constituents.

3. Nutritional Support to Hair Follicles

Hair follicles require continuous nutritional support for keratin synthesis and hair shaft formation. Herbal hair oils provide essential fatty acids, vitamins (A, E, and C), minerals, and amino acids that contribute to follicular nourishment and strengthening of hair roots.[38] Amla, in particular, is rich in vitamin C and antioxidants, which support collagen synthesis and improve hair shaft resilience.

Carrier oils such as coconut oil penetrate the hair shaft due to their low molecular weight and affinity for hair proteins, thereby reducing protein loss and strengthening hair fibers.[39] This nutritional and conditioning effect helps prevent hair breakage and split ends.

4. Antioxidant and Anti-aging Effects

Oxidative stress plays a significant role in hair follicle aging, hair loss, and premature greying. Reactive oxygen species (ROS) generated due to environmental pollution, ultraviolet radiation, and metabolic stress can damage follicular cells and disrupt the hair growth cycle.[40] Herbal hair oils contain potent antioxidants such as polyphenols, flavonoids, and tannins that neutralize free radicals and protect hair follicles from oxidative damage.

By reducing oxidative stress, herbal hair oils help preserve melanocyte function within hair follicles, thereby delaying premature greying and maintaining natural hair pigmentation.[41]

5. Anti-inflammatory Action

Inflammation of the scalp is a common underlying factor in many hair disorders, including alopecia areata, seborrheic dermatitis, and psoriasis. Herbal hair oils containing anti-inflammatory herbs such as aloe vera, neem, and brahmi help suppress inflammatory mediators and soothe irritated scalp tissue.[42] This anti-inflammatory effect protects hair follicles from immune-mediated damage and supports normal hair cycling.

6. Antimicrobial and Anti-dandruff Activity

Microbial infections of the scalp, particularly fungal infections caused by *Malassezia* species, contribute to dandruff, itching, and hair fall. Herbal hair oils formulated with neem, tea tree oil, tulsi, and other antimicrobial herbs exhibit significant antifungal and antibacterial

activity.[43] These properties help maintain scalp hygiene, reduce dandruff, and prevent follicular blockage.

7. Sebum Regulation and Scalp Conditioning

Herbal hair oils help regulate sebum production by maintaining the natural lipid balance of the scalp. Excessive sebum can clog hair follicles, while insufficient sebum leads to dryness and brittleness. Herbal oils restore this balance by moisturizing the scalp and forming a protective lipid layer over the hair shaft.[44] This conditioning effect improves hair smoothness, shine, and manageability.

8. Stress Reduction and Neuroendocrine Effects

Chronic stress is a known trigger for hair loss through neuroendocrine pathways. Regular application and massage of herbal hair oils have been shown to induce relaxation, reduce stress hormone levels, and improve overall scalp health.[45] Herbs such as brahmi and jatamansi possess adaptogenic properties that may indirectly support hair growth by modulating stress responses.

Medicinal Plants Used in Herbal Hair Oil

Herbal hair oils are predominantly polyherbal formulations composed of medicinal plants that possess hair growth–promoting, scalp-conditioning, antimicrobial, anti-inflammatory, and antioxidant properties. The selection of herbs is based on traditional usage, ethnopharmacological relevance, and emerging scientific evidence. These medicinal plants act synergistically to improve hair follicle health, enhance hair growth, and prevent various hair and scalp disorders.[46]

1. *Eclipta alba* (Bhringraj)

Eclipta alba, commonly known as bhringraj, is widely regarded as the “king of hair” in Ayurvedic medicine. It has been traditionally used to promote hair growth, prevent hair fall, and delay premature greying. Phytochemical studies reveal the presence of coumestans (wedelolactone), flavonoids, alkaloids, and polyacetylenes, which contribute to its hair growth–promoting activity.[47] Experimental studies have demonstrated that bhringraj extract stimulates hair follicle proliferation, increases anagen phase duration, and enhances hair density in animal models.[48]

2. *Phyllanthus emblica* (Amla)

Amla is a rich source of vitamin C, tannins, and polyphenolic compounds, making it a potent antioxidant herb. It nourishes hair follicles, strengthens hair roots, and prevents oxidative damage to follicular cells. Amla is also known to improve hair pigmentation and delay premature greying by preserving melanocyte function within hair follicles[49] Its inclusion in herbal hair oil formulations enhances hair thickness, shine, and overall hair vitality.

3. *Azadirachta indica* (Neem)

Neem possesses strong antimicrobial, antifungal, and anti-inflammatory properties, which make it particularly useful in the management of dandruff and scalp infections. Active constituents such as nimbin, nimbidin, and azadirachtin inhibit the growth of dandruff-causing microorganisms, including *Malassezia* species.[50] Neem also helps reduce scalp inflammation and itching, creating a healthy environment for hair growth.

4. *Hibiscus rosa-sinensis* (Hibiscus)

Hibiscus flowers and leaves are rich in amino acids, flavonoids, and mucilage, which nourish hair follicles and improve hair shaft strength. Traditional use suggests that hibiscus promotes hair growth, prevents split ends, and enhances hair texture. Scientific studies have reported increased hair length and follicular density following topical application of hibiscus extracts.[51]

5. *Bacopa monnieri* (Brahmi)

Brahmi is known for its adaptogenic and neuroprotective properties. In hair care, it strengthens hair roots, reduces hair fall, and improves scalp circulation. Brahmi helps alleviate stress-induced hair loss by modulating neuroendocrine pathways, thereby indirectly supporting hair growth.[52]

6. *Aloe barbadensis* (Aloe vera)

Aloe vera is widely used in hair care formulations due to its moisturizing, soothing, and anti-inflammatory properties. It contains enzymes, vitamins, minerals, and polysaccharides that promote scalp hydration and reduce irritation. Aloe vera also helps maintain scalp pH and improves hair manageability.[53]

7. *Centella asiatica* (Mandukaparni)

Centella asiatica enhances microcirculation and collagen synthesis, which are essential for maintaining healthy hair follicles. Its antioxidant and anti-inflammatory properties protect hair follicles from oxidative stress and inflammatory damage, supporting sustained hair growth.[54]

8. *Lawsonia inermis* (Henna)

Henna is traditionally used as a natural hair dye and conditioner. It strengthens the hair shaft, improves cuticle integrity, and imparts shine to hair. Henna also exhibits antimicrobial activity that helps maintain scalp hygiene.[55]

9. *Trigonella foenum-graecum* (Fenugreek)

Fenugreek seeds are rich in proteins, nicotinic acid, and lecithin, which strengthen hair roots and prevent hair thinning. They also help reduce dandruff and scalp irritation due to their anti-inflammatory properties.[56]

Synergistic Role of Polyherbal Combinations

The therapeutic efficacy of herbal hair oils is significantly enhanced when multiple herbs are combined in appropriate proportions. Polyherbal formulations offer synergistic effects, improved bioavailability, and broader therapeutic coverage compared to single-herb formulations. This synergism forms the basis of most traditional and modern herbal hair oil preparations.[57]

Carrier Oils Used in Herbal Hair Oil

Carrier oils form the base of herbal hair oil formulations and play a crucial role in the extraction, stabilization, and delivery of bioactive phytoconstituents to the scalp and hair follicles. In addition to acting as vehicles, carrier oils themselves possess therapeutic properties such as emollient, moisturizing, antioxidant, and antimicrobial activities. The choice of carrier oil significantly influences the efficacy, penetration, stability, and sensory attributes of herbal hair oil formulations.[58]

1. Coconut Oil (*Cocos nucifera*)

Coconut oil is one of the most commonly used carrier oils in herbal hair oil formulations due to its excellent penetration ability and affinity for hair proteins. It is rich in medium-chain fatty acids, particularly lauric acid, which enables it to penetrate the hair shaft and reduce

protein loss during washing and grooming.[59] Coconut oil also exhibits antimicrobial properties that help maintain scalp hygiene and prevent microbial infections. Its regular use improves hair strength, reduces breakage, and enhances hair shine.

2. Sesame Oil (*Sesamum indicum*)

Sesame oil has been extensively used in Ayurvedic formulations owing to its nourishing, antioxidant, and warming properties. It contains sesamol, sesamin, and vitamin E, which provide protection against oxidative damage and environmental stressors.[60] Sesame oil improves blood circulation when applied with massage and enhances transdermal absorption of herbal constituents, making it a preferred base oil in medicated hair oils.

3. Castor Oil (*Ricinus communis*)

Castor oil is a viscous oil rich in ricinoleic acid, which exhibits anti-inflammatory and antimicrobial properties. It is traditionally used to promote hair thickness, strengthen hair roots, and prevent scalp dryness. Castor oil also enhances scalp hydration and helps reduce dandruff and itching.[61] Due to its high viscosity, it is often blended with lighter oils to improve spreadability and user acceptability.

4. Almond Oil (*Prunus amygdalus*)

Almond oil is a light, non-greasy oil rich in vitamin E, essential fatty acids, and minerals. It nourishes hair follicles, improves hair elasticity, and protects hair from oxidative damage. Almond oil also helps smooth the hair cuticle, thereby reducing friction and enhancing hair softness and manageability.[62]

5. Olive Oil (*Olea europaea*)

Olive oil contains monounsaturated fatty acids, polyphenols, and squalene, which contribute to its moisturizing and antioxidant properties. It acts as an effective emollient, improving scalp hydration and reducing hair dryness. Olive oil also enhances the penetration of herbal extracts into the scalp due to its lipid-soluble nature.[63]

6. Mustard Oil (*Brassica juncea*)

Mustard oil is traditionally used in hair care for its warming and circulatory-stimulating effects. It contains omega-3 and omega-6 fatty acids that nourish hair follicles and improve scalp health. Mustard oil is believed to stimulate hair growth by increasing blood flow to the

scalp; however, its strong odor limits its standalone use and it is often blended with other oils.[64]

7. Sunflower Oil (*Helianthus annuus*)

Sunflower oil is rich in linoleic acid and vitamin E, making it beneficial for maintaining scalp moisture and preventing oxidative damage. It is lightweight and suitable for individuals with sensitive scalp or fine hair. Sunflower oil also helps restore the lipid barrier of the scalp and hair shaft.[65]

Role of Carrier Oils in Enhancing Bioavailability

Carrier oils facilitate the extraction of lipid-soluble phytoconstituents from medicinal plants and enhance their penetration through the stratum corneum and hair follicle openings. The lipid matrix of carrier oils improves residence time on the scalp, allowing sustained release of active compounds and prolonged therapeutic action.[66] The synergistic interaction between carrier oils and herbal extracts forms the foundation of effective herbal hair oil formulations.

Methods of Preparation of Herbal Hair Oil

The method of preparation plays a decisive role in determining the quality, efficacy, and stability of herbal hair oil formulations. Traditional systems of medicine such as Ayurveda describe several techniques for preparing medicated oils to ensure optimal extraction and preservation of bioactive phytoconstituents. Modern pharmaceutical approaches have adapted these methods to improve standardization, reproducibility, and safety while maintaining therapeutic efficacy.[67]

1. Taila Kalpana (Ayurvedic Oil Processing Method)

Taila Kalpana is the classical Ayurvedic method for preparing medicated oils and is widely used for herbal hair oil formulations. This process involves boiling herbal paste (*Kalka*), herbal liquid (*Drava*—decoction, juice, or milk), and base oil (*Sneha*) in a specific ratio until complete transfer of active constituents into the oil occurs.[68]

Typically, the proportion used is 1 part herbal paste, 4 parts oil, and 16 parts liquid. The mixture is heated at controlled temperature with continuous stirring until all the aqueous content evaporates, leaving behind a clear medicated oil. Taila Kalpana ensures enhanced extraction of both lipid-soluble and water-soluble phytoconstituents, resulting in superior therapeutic efficacy.[69]

2. Infusion Method

The infusion method is a simple and commonly used technique in both traditional and household-level preparation of herbal hair oils. In this method, dried or fresh plant materials are soaked in a carrier oil for a prolonged period under ambient or mild heating conditions. The process allows gradual diffusion of active constituents into the oil matrix.[70] Hot infusion involves gently heating the oil and herbs to accelerate extraction, while cold infusion relies on time-dependent extraction at room temperature. Although this method is economical and easy to perform, it may result in lower extraction efficiency compared to Taila Kalpana and lacks precise standardization.[71]

3. Decoction Method

In the decoction method, herbal materials are boiled in water to obtain a concentrated aqueous extract, which is subsequently mixed with a carrier oil and heated until complete evaporation of water occurs. This method is particularly suitable for extracting heat-stable and water-soluble phytoconstituents such as tannins, flavonoids, and glycosides.[72]

The decoction method is often employed in polyherbal formulations where multiple herbs are used simultaneously. However, prolonged heating may lead to degradation of thermolabile compounds if temperature control is inadequate.[73]

4. Direct Boiling Method

In this method, herbal materials are directly boiled with the base oil until the active constituents are transferred into the oil. This technique is simple but requires careful monitoring to prevent charring of plant material and degradation of active compounds. Direct boiling is generally used for robust herbs and roots that require prolonged heating for effective extraction.[74]

5. Modern Extraction-Assisted Methods

Advancements in pharmaceutical technology have introduced modern extraction techniques such as Soxhlet extraction, ultrasound-assisted extraction, and microwave-assisted extraction for herbal oil preparation. These methods enhance extraction efficiency, reduce processing time, and improve reproducibility.[75]

However, despite their advantages, modern techniques may require specialized equipment and solvents, making them less suitable for traditional herbal oil preparation. Therefore, a

balance between traditional wisdom and modern technology is essential for developing standardized and effective herbal hair oil formulations.[76]

Importance of Standardization in Preparation Methods

Standardization of preparation methods is crucial to ensure batch-to-batch consistency, safety, and therapeutic efficacy of herbal hair oils. Factors such as temperature, duration of heating, herb-to-oil ratio, and quality of raw materials significantly influence the final product quality.[77] Adoption of Good Manufacturing Practices (GMP) and quality control parameters can enhance the acceptability of herbal hair oils in the modern cosmetic and pharmaceutical markets.

Formulation Development of Herbal Hair Oil

Formulation development of herbal hair oil involves systematic selection of medicinal plants, carrier oils, and appropriate preparation techniques to ensure safety, efficacy, stability, and consumer acceptability. A scientifically developed formulation integrates traditional knowledge with pharmaceutical principles to obtain a standardized and reproducible product suitable for cosmetic and therapeutic use.[78]

Selection of Herbal Ingredients

The selection of herbs is based on their traditional use in hair care, pharmacological activity, availability, and safety profile. Herbs with proven hair growth–promoting, anti-dandruff, antioxidant, antimicrobial, and conditioning properties are preferred. Polyherbal combinations are commonly used to achieve synergistic effects and broader therapeutic coverage.[79]

Selection of Base Oil

The choice of base oil depends on its compatibility with herbal ingredients, stability, penetration ability, and sensory properties. Oils such as coconut, sesame, almond, and castor oil are widely used either alone or in combination. The base oil should be non-irritant, stable under processing conditions, and capable of effectively extracting and delivering bioactive compounds to hair follicles.[80]

Optimization of Herb-to-Oil Ratio

The herb-to-oil ratio plays a critical role in determining the concentration of active constituents in the final product. Insufficient herb concentration may lead to reduced efficacy,

whereas excessive herbal content may affect stability and aesthetics. Optimization studies help determine the ideal ratio for maximum therapeutic benefit without compromising product quality.[81]

Incorporation of Additives

Natural additives such as essential oils (e.g., lavender, rosemary, tea tree), antioxidants (vitamin E), and natural preservatives may be incorporated to enhance fragrance, stability, and shelf life. Essential oils also contribute additional therapeutic benefits, including improved scalp circulation and antimicrobial action.[82]

Quality Control During Formulation

Strict quality control measures are essential throughout the formulation process. Parameters such as raw material authentication, moisture content, microbial load, and absence of heavy metals or pesticide residues must be ensured. Compliance with Good Manufacturing Practices (GMP) is crucial for producing safe and high-quality herbal hair oils.[83]

Packaging and Storage Considerations

Packaging plays a vital role in maintaining the stability and quality of herbal hair oil. Amber-colored glass or high-quality plastic containers are preferred to protect the formulation from light-induced degradation. Proper storage conditions help prevent oxidation and microbial contamination, thereby extending shelf life.[84]

Evaluation Parameters of Herbal Hair Oil

Evaluation of herbal hair oil is essential to assess its quality, safety, stability, and performance. Both physicochemical and biological parameters are employed to ensure product consistency and therapeutic effectiveness.[85]

1. Organoleptic Evaluation

Organoleptic parameters include color, odor, clarity, and texture. These characteristics influence consumer acceptability and provide preliminary information about formulation stability.[87]

2. Physicochemical Evaluation

Key physicochemical parameters include pH, viscosity, specific gravity, refractive index, acid value, saponification value, and peroxide value. These parameters help assess oil purity, stability, and susceptibility to oxidation.[87]

3. Skin Irritation and Sensitivity Test

Safety evaluation involves conducting skin irritation and sensitivity studies to ensure that the formulation does not cause redness, itching, or allergic reactions. Patch tests are commonly used to confirm dermal safety.[88]

4. Microbial Load Testing

Microbial testing ensures that the formulation is free from pathogenic microorganisms. Acceptable microbial limits must comply with regulatory standards for cosmetic products[89]

5. Stability Studies

Stability studies evaluate the formulation under various environmental conditions such as temperature, humidity, and light exposure. These studies help predict shelf life and ensure product consistency over time.[90]

Preclinical Studies on Herbal Hair Oil

Preclinical studies play a pivotal role in scientifically validating the traditional claims associated with herbal hair oil formulations. These studies primarily involve in vitro and in vivo experimental models to evaluate hair growth–promoting activity, follicular stimulation, anti-dandruff efficacy, and safety profile prior to clinical use. Such investigations provide mechanistic insights and establish dose–response relationships for herbal constituents.[91]

Animal Models for Hair Growth Evaluation

Rodent models, particularly albino rats and C57BL/6 mice, are widely employed for assessing hair growth activity. Hair growth is evaluated by parameters such as onset time of hair growth, duration of the anagen phase, hair length, hair density, and follicular count. Herbal oils containing extracts of *Eclipta alba*, *Hibiscus rosa-sinensis*, and *Phyllanthus emblica* have demonstrated significant reduction in telogen phase duration and earlier initiation of anagen phase compared to control groups.[92]

Histopathological Studies

Histological examination of skin sections from treated animals reveals increased number and size of hair follicles, enhanced dermal thickness, and increased vascularization around follicles. These changes indicate stimulation of follicular activity and improved nutrient supply to hair roots following application of herbal hair oils.[93]

Anti-Dandruff and Antimicrobial Studies

Preclinical antimicrobial studies have shown that herbal hair oil formulations exhibit inhibitory activity against dandruff-causing organisms such as *Malassezia furfur*, *Staphylococcus aureus*, and *Candida albicans*. Herbs like neem, tulsi, and tea tree oil contribute significantly to antimicrobial efficacy, reducing scalp microbial load and inflammation.[94]

Anti-Inflammatory and Antioxidant Activity

Oxidative stress and scalp inflammation are major contributors to hair loss. Herbal hair oils rich in polyphenols and flavonoids exhibit significant antioxidant activity, as evidenced by reduced lipid peroxidation and increased superoxide dismutase and catalase activity in scalp tissues. Anti-inflammatory effects further protect hair follicles from cytokine-mediated damage.[95]

Dermal Toxicity and Safety Assessment

Dermal toxicity studies, including acute and repeated dose dermal toxicity tests, have demonstrated that most herbal hair oil formulations are non-irritant and safe for topical use. Absence of erythema, edema, and histological abnormalities confirms their dermal safety.[96]

Clinical Studies and Human Evidence

Clinical evaluation is essential to confirm the safety and efficacy of herbal hair oil formulations in human subjects. Although large-scale randomized controlled trials are limited, several clinical and observational studies support the beneficial effects of herbal hair oils in managing hair fall, dandruff, and scalp disorders.[97]

Hair Fall Reduction and Hair Growth Promotion

Clinical studies involving regular application of herbal hair oils for periods ranging from 8 to 24 weeks have reported significant reduction in hair fall, increased hair thickness, and improved hair density. Participants also reported subjective improvements in hair texture, shine, and manageability.[98]

Management of Dandruff and Scalp Conditions

Herbal hair oils containing neem, aloe vera, and essential oils have shown considerable improvement in dandruff severity, scalp itching, and dryness. Reduction in flaking and

microbial colonization has been observed without adverse effects commonly associated with synthetic anti-dandruff agents.[99]

Patient Compliance and Acceptability

Herbal hair oils are generally well accepted due to their natural origin, minimal side effects, and additional benefits such as scalp relaxation and stress reduction through massage. Improved patient compliance contributes significantly to long-term therapeutic outcomes.[100]

Safety, Toxicity, and Regulatory Aspects

Despite their natural origin, herbal hair oils must undergo safety evaluation and regulatory compliance to ensure consumer protection. Factors such as contamination, adulteration, and improper processing may compromise product safety.[101]

Toxicity Considerations

Most medicinal plants used in hair oil formulations are considered safe when used topically. However, excessive use of essential oils or poor-quality raw materials may cause irritation or sensitization. Therefore, toxicity assessment and controlled formulation are essential.[102]

Regulatory Framework

In India, herbal hair oils are regulated as cosmetic products under the Drugs and Cosmetics Act, 1940, and must comply with Bureau of Indian Standards (BIS) guidelines. Globally, regulatory requirements vary, but adherence to GMP and quality standards is mandatory for market approval.[103]

CONCLUSION

Herbal hair oils represent an important class of traditional cosmetic and therapeutic preparations that have been used for centuries to promote hair growth, maintain scalp health, and manage hair-related disorders. This review comprehensively highlights the role of medicinal plants, carrier oils, formulation methods, mechanisms of action, and scientific validation of herbal hair oil formulations. The accumulated evidence strongly supports the traditional claims associated with herbal hair oils, emphasizing their multifactorial benefits in hair care.

Medicinal plants such as *Eclipta alba*, *Phyllanthus emblica*, *Hibiscus rosa-sinensis*, *Azadirachta indica*, and *Bacopa monnieri* play a central role in improving hair follicle function through antioxidant, anti-inflammatory, antimicrobial, and follicle-stimulating

activities. These herbs act synergistically when combined in polyherbal formulations, offering broader therapeutic efficacy compared to single-ingredient products. Carrier oils such as coconut, sesame, almond, and castor oil not only serve as vehicles for phytoconstituent delivery but also contribute significantly to scalp nourishment, hair shaft protection, and enhanced penetration of bioactive compounds.

Traditional preparation techniques like Taila Kalpana, infusion, and decoction methods ensure effective extraction and stabilization of active constituents, while modern pharmaceutical approaches improve standardization and reproducibility. Formulation development and evaluation parameters, including physicochemical testing, microbial analysis, stability studies, and safety assessments, are essential to ensure product quality, efficacy, and consumer safety. Preclinical studies provide mechanistic insights into hair growth promotion, follicular regeneration, and dandruff control, whereas clinical evidence supports the effectiveness of herbal hair oils in reducing hair fall, improving hair density, and managing scalp conditions with minimal adverse effects.

Despite their proven benefits, challenges such as lack of large-scale randomized clinical trials, variability in raw material quality, and limited regulatory harmonization remain barriers to global acceptance. Future research should focus on advanced clinical studies, molecular-level mechanism elucidation, improved standardization protocols, and development of evidence-based guidelines for herbal hair oil formulations. Integration of modern analytical techniques with traditional knowledge will further enhance the credibility and therapeutic potential of herbal hair oils.

In conclusion, herbal hair oils offer a safe, effective, and holistic approach to hair and scalp care. With increasing consumer preference for natural and sustainable products, scientifically validated herbal hair oils hold significant promise for future cosmetic and dermatological applications. Strengthening research, quality control, and regulatory frameworks will play a crucial role in expanding their acceptance in modern healthcare and cosmetic industries.

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