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Review Article

Understanding Alopecia and the Potential of Herbal Interventions

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ABSTRACT

Androgenetic Alopecia (AGA), a common form of hair loss, significantly impacts individuals globally. While conventional treatments exist, interest in natural alternatives is growing due to potential side effects and varying efficacy. This review explores the scientific evidence for ten herbal plants Saw Palmetto, Stinging Nettle, Rosemary, Bhringraj, Amla, Ginseng, Green Tea, Pumpkin Seed Oil, Hibiscus, and Fenugreek in managing AGA. These botanicals contain diverse phytochemicals that may inhibit 5-alpha-reductase, reduce inflammation and oxidative stress, improve scalp circulation, and stimulate hair follicle cells. Human studies, particularly for rosemary oil, pumpkin seed oil, and some polyherbal formulations, show promising results, often comparable to conventional treatments like minoxidil. However, more robust, large-scale clinical trials are needed to confirm their efficacy and standardize their use.

Keywords: Alopecia, Androgenetic Alopecia, Herbal Remedies, Hair Loss.

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INTRODUCTION

Alopecia, the medical term for hair loss, is a widespread concern affecting millions of individuals globally, impacting self-esteem and quality of life (Hunt & McHale, 2005). While various types exist, the most common form is Androgenetic Alopecia (AGA), also known as male pattern baldness or female pattern hair loss (Olsen *et al*., 2005). AGA is characterized by a progressive miniaturization of hair follicles in susceptible areas of the scalp, leading to shorter, finer hairs and eventual cessation of hair production (Kaufman, 2002).

The hair growth cycle consists of three main phases: anagen (active growth), catagen (transitional), and telogen (resting) (Paus & Cotsarelis,1999). In AGA, the anagen phase becomes progressively shorter, while the telogen phase lengthens, resulting in increased shedding and reduced hair density. A key factor driving this process is the androgen Dihydrotestosterone (DHT). The enzyme 5-alpha-reductase (5αR), present in scalp hair follicles, converts testosterone into the more potent DHT. Individuals with AGA often exhibit higher levels of 5αR activity and/or increased sensitivity of hair follicles to DHT (Ellis, 2001). DHT binds to androgen receptors in dermal papilla cells, initiating signaling cascades that lead to follicle miniaturization and altered hair cycling.

Beyond the central role of androgens, other factors contribute to hair loss pathophysiology, including microinflammation around the hair follicle, oxidative stress damaging follicular cells, inadequate scalp microcirculation compromising nutrient delivery, and genetic predisposition (Mahe *et al*., 2000; Trueb, 2015).

Current FDA-approved treatments for AGA primarily include topical minoxidil (a vasodilator and potential potassium channel opener) and oral finasteride (a type II 5αR inhibitor) (Adil & Godwin, 2017). While effective for many, these treatments can have side effects, may require continuous use, and do not work for everyone (Mysore, 2012). This has spurred significant interest in alternative and complementary therapies, particularly herbal remedies, which have been used traditionally for centuries to maintain hair health and combat hair loss.

Many botanicals contain complex mixtures of phytochemicals such as phytosterols, fatty acids, polyphenols, flavonoids, terpenoids, and alkaloids-that may target multiple pathways involved in hair loss (Rossi *et al*., 2012). Potential mechanisms include inhibition of 5αR, antioxidant effects to combat oxidative stress, anti-inflammatory actions to reduce follicular microinflammation, improvement of scalp circulation, direct stimulation of hair follicle cells (like dermal papilla cells), and modulation of the hair growth cycle (Zgonc *et al*., 2020).

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This review examines the scientific evidence supporting the use of ten specific herbal plants with search term as, Saw Palmetto (*Serenoa repens*), Stinging Nettle (*Urtica dioica*), Rosemary (*Rosmarinus officinalis*), Bhringraj (*Eclipta prostrata*), Amla (*Phyllanthus emblica*), Ginseng (*Panax ginseng*), Green Tea (*Camellia sinensis*), Pumpkin Seed Oil (*Cucurbita pepo*), Hibiscus (*Hibiscus rosa-sinensis*), and Fenugreek (*Trigonella foenum-graecum*) for preventing or managing alopecia, primarily focusing on AGA where applicable (Figure 1). We will delve into their traditional uses, relevant phytochemicals, proposed mechanisms, findings from *in vitro*, animal, and human studies, and safety considerations. It is crucial, however, to preface this review with the note that evidence quality varies significantly, and robust, large-scale clinical trials are often lacking compared to pharmaceutical interventions. Consultation with a healthcare professional, particularly a dermatologist, is essential for accurate diagnosis and personalized treatment recommendations.

Herbal Plants and their Potential Role in Alopecia Management

Saw Palmetto (Serenoa repens)

The berries of the Saw Palmetto palm, native to the southeastern United States, have a long history of use by Native Americans. Traditionally, it was employed for urinary and reproductive issues in men (Suzuki *et al.*, 2009). Its application for hair loss is more recent, stemming from its recognized effects on androgen metabolism, particularly in relation to Benign Prostatic Hyperplasia (BPH) (Pais *et al.*, 2016).

The liposterolic extract of Saw Palmetto berries is rich in fatty acids (including lauric, oleic, myristic, and palmitic acids) and phytosterols (such as beta-sitosterol, campesterol, stigmasterol) (Habib *et al.*, 1995).

The primary proposed mechanism is the inhibition of both type I and type II isoforms of 5α-reductase, thereby reducing the conversion of testosterone to DHT in target tissues, including the scalp hair follicle (Bayne *et al.*, 1999). Beta-sitosterol, a major phytosterol component, is particularly implicated in this inhibitory activity (Dhariwala et al., 2019). Additionally, Saw Palmetto extract may interfere with the binding of DHT to androgen receptors and possess anti-inflammatory properties (Ravenna *et al.*, 1996).

In vitro studies: Multiple studies have demonstrated the ability of Saw Palmetto extracts (specifically the lipidosterolic fraction) to inhibit 5αR activity in cell-free assays and in cultured cells like prostate cells and skin fibroblasts (Di Silverio *et al.*, 1998). Some studies suggest it inhibits both type I and type II isoenzymes, unlike finasteride which primarily targets type II. Research has also shown inhibition of DHT binding to androgen receptors.

Animal studies: Studies directly evaluating Saw Palmetto's effect on hair growth in standard animal models are less common compared to its investigation for BPH.

Human studies: Several clinical trials and pilot studies have investigated Saw Palmetto for AGA, yielding mixed but often positive results. A randomized, double-blind, placebo-controlled study in men with mild to moderate AGA found that a Saw Palmetto extract (320 mg/day) taken orally for 2 years resulted in improved hair growth assessed by investigators in 38% of participants, compared to minimal improvement in the placebo group (Marks *et al.*, 2001). Another small study comparing oral Saw Palmetto (200 mg twice daily) with finasteride (1 mg daily) found finasteride more effective for vertex hair growth, but Saw Palmetto showed positive effects, particularly in the vertex area, for some participants (Rossi *et al.*, 2012). A systematic review evaluating botanical interventions for AGA concluded that Saw Palmetto showed promising results in several studies, with improvements in total hair count and subjective assessments, although the quality of evidence was often limited by small sample sizes or methodological issues (Dhariwala & Ravikumar, 2019). Topical formulations containing Saw Palmetto have also been explored, with some pilot studies suggesting potential benefits (Wessagowit *et al.*, 2016).

Saw Palmetto is generally well-tolerated when taken orally, with mild gastrointestinal side effects being the most common complaint. It is typically available as standardized lipidosterolic extracts in capsules or as part of multi-ingredient hair supplements or topical lotions/shampoos. Due to potential hormonal effects, caution is advised, especially for women (particularly pregnant or breastfeeding) and individuals with hormone-sensitive conditions.

Stinging Nettle (*Urtica dioica*)

Stinging Nettle has been used for centuries in traditional European medicine for a wide range of ailments, including arthritis, allergies, urinary problems, and as a general tonic (Johnson *et al.*, 2013). Its use as a hair rinse or tonic to stimulate growth and improve hair quality is also documented in folk medicine (Upton, 2013).

Nettle roots contain lignans, polysaccharides, sterols (including beta-sitosterol), lectins (Urtica dioica agglutinin), and phenolic compounds (Chrubasik *et al.*, 2007). The leaves are rich in vitamins (A, C, K), minerals (iron, silica), flavonoids (quercetin, rutin), carotenoids, and amines (histamine, serotonin - responsible for the stinging sensation in fresh leaves). For hair loss applications, root extracts are more commonly cited regarding potential hormonal effects, while leaf extracts are associated with anti-inflammatory and nutrient properties.

Similar to Saw Palmetto, nettle root extract is proposed to inhibit 5αR activity, potentially due to its steroidal components

and lignans (Nahata & Dixit, 2012). It may also interfere with the binding of Sex Hormone-Binding Globulin (SHBG) to receptors, potentially influencing free androgen levels. The anti-inflammatory properties, particularly associated with leaf extracts containing flavonoids and phenolic acids, could help mitigate follicular microinflammation implicated in AGA. The silica content in leaves might contribute to hair strength (although systemic effects of dietary silica on hair are debated).

In vitro studies: Research primarily focused on BPH has shown that nettle root extracts can inhibit 5αR activity, though possibly less potently than Saw Palmetto. Studies have also demonstrated inhibition of aromatase, another enzyme involved in steroid metabolism. Anti-inflammatory effects, such as inhibition of NF-κB pathways and pro-inflammatory cytokine release, have been shown for nettle leaf extracts (Riehemann *et al*., 1999). Direct studies on hair follicle cells are less common.

Animal studies: Specific animal models testing *Urtica dioica* extracts solely for hair growth are scarce.

Human studies: High-quality clinical trials evaluating Stinging Nettle alone for AGA are lacking. It is frequently included as one component in multi-herb supplements marketed for hair loss or BPH (Lopatkin *et al*., 2005). A study on a combination product containing Saw Palmetto and Nettle root for BPH reported benefits, but isolating the effect of nettle is difficult. Given its traditional use and plausible mechanisms (anti-inflammatory, potential weak 5αR inhibition), it remains a popular ingredient, but robust clinical validation specifically for alopecia is needed.

Nettle leaf and root preparations are generally considered safe when used appropriately. Handling fresh leaves causes skin irritation due to stinging hairs. Oral supplements (root or leaf extracts) may occasionally cause mild stomach upset. Topical use as a rinse or in shampoos is common. Caution is advised for individuals on medications for diabetes, blood pressure, or blood thinning due to potential interactions.

Rosemary (*Rosmarinus officinalis*)

Rosemary, a Mediterranean herb, has a long history of culinary and medicinal use. It was traditionally employed to improve memory, relieve muscle pain, and stimulate circulation (de Oliveira *et al*., 2019). Applying rosemary-infused water or oil to the scalp to promote hair growth and prevent baldness is a well-established practice in folk medicine.

Rosemary leaves contain phenolic compounds, including rosmarinic acid, carnosic acid, and carnosol, which are potent antioxidants and anti-inflammatories. The essential oil is rich in monoterpenes like 1,8-cineole (eucalyptol), camphor, α-pinene, and borneol.

Rosemary oil may act as a vasodilator, increasing blood flow to the hair follicles, which could enhance nutrient delivery and stimulate growth (Koyama & Heinbockel, 2020). Carnosic acid and rosmarinic acid can suppress pro-inflammatory pathways (like NF-κB), potentially reducing follicular microinflammation (Raskovic *et al*., 2014). Potent antioxidant properties help protect hair follicle cells from oxidative stress caused by ROS. Some *in vitro* evidence suggests rosemary extract might inhibit 5αR activity (Murata *et al*., 2013). Some components might stimulate nerve endings in the scalp.

In vitro studies: Studies have confirmed the potent antioxidant and anti-inflammatory activities of rosemary extracts and its key phenolic diterpenes (carnosic acid, carnosol). One study showed that rosemary leaf extract inhibited 5αR activity and stimulated hair growth in mice when applied topically.

Animal studies: The aforementioned study demonstrated that topical application of rosemary leaf extract on mice where hair growth was interrupted by testosterone treatment resulted in significant hair regrowth, linking this effect to 5αR inhibition. Other studies have also shown hair growth-promoting effects of rosemary oil in animal models (Azadbakht *et al*., 2017).

Human studies: A notable randomized comparative trial directly compared the efficacy of rosemary oil lotion (standardized to contain specific amounts of 1,8-cineole and camphor) with 2% minoxidil lotion in 100 patients with AGA over 6 months (Panahi *et al*., 2015). Both groups experienced a significant increase in hair count at the 6-month mark compared to baseline and the 3-month mark ($p<0.05$). Importantly, there was no statistically significant difference in hair count increase between the rosemary oil group and the minoxidil group at 6 months. However, scalp itching was significantly more frequent in the minoxidil group. This study provides promising evidence for rosemary oil as a potential alternative to minoxidil for AGA, although larger trials are warranted for confirmation.

Topical rosemary oil is generally safe but can cause skin irritation or allergic reactions in sensitive individuals; dilution in a carrier oil is recommended. Oral consumption of large amounts should be avoided, especially during pregnancy. Rosemary oil or extract is commonly found in shampoos, conditioners, and scalp treatments.

Bhringraj (*Eclipta prostrata* or *Eclipta alba*)

Bhringraj, meaning "King of Hair," is one of the most revered herbs in Ayurveda for hair care. It is traditionally used extensively in oils, powders, and pastes to prevent hair loss, promote hair growth, combat dandruff, and delay premature graying (Sharma, 2017). It's considered a 'Rasayana' (rejuvenator) for hair.

Eclipta prostrata contains various bioactive compounds, including coumestans (wedelolactone, demethylwedelolactone), triterpenoid saponins (eclalbasaponins), flavonoids (luteolin, apigenin), thiophene derivatives, and alkaloids (Figure 2) (Jahan *et al*., 2014).

The exact mechanisms are not fully elucidated but Compounds like wedelolactone might directly stimulate dermal papilla cells or promote the transition of hair follicles from the telogen (resting) phase to the anagen (growth) phase (Roy *et al.*, 2008). Potential improvement in scalp blood circulation. Flavonoids and other phenolics provide antioxidant protection, while certain compounds may possess anti-inflammatory activity relevant to scalp health (Thakur & Mengi, 2005). Some preliminary evidence suggests potential weak inhibition of 5αR, though this is less emphasized than its growth-promoting effects (Kumar *et al.*,2012).

In vitro studies: Research has demonstrated antioxidant and anti-inflammatory activities of *Eclipta* extracts. Studies focusing specifically on hair follicle cells are emerging.

Animal studies: Several animal studies provide strong support for the traditional claims. Topical application of petroleum ether and methanol extracts of *Eclipta prostrata* leaves on shaved albino rats significantly reduced the time taken to initiate hair growth and increased the number of hair follicles in the anagen phase compared to control groups. In some studies, the efficacy was comparable to 2% minoxidil (Begum *et al.*, 2015) These studies often attribute the effect to promoting the anagen phase of the hair cycle.

Human studies: Despite its widespread traditional use and promising animal data, high-quality clinical trials evaluating standardized Bhringraj preparations specifically for AGA in humans are currently lacking in major peer-reviewed journals. Its efficacy in humans is largely based on traditional knowledge and anecdotal evidence, often used in polyherbal formulations.

Bhringraj is generally considered safe for topical and oral use in traditional practices. It is widely available as hair oils (often infused in sesame or coconut oil), powders for hair packs, and in capsule form as part of Ayurvedic supplements. Allergic reactions are possible but rare.

Amla/Indian Gooseberry (*Phyllanthus emblica* or *Emblica officinalis*)

Amla is another highly esteemed 'Rasayana' herb in Ayurveda, valued for its rejuvenating properties and wide range of health benefits (Krishnaveni & Mirunalini, 2010). It has been used for millennia as a general tonic, for digestive health, and notably, as a key ingredient in hair care formulations to strengthen hair roots, promote growth, add shine, and prevent premature graying (Baliga & Dsouza, 2011).

Amla fruit is exceptionally rich in Vitamin C (ascorbic acid), often complexed with tannins (e.g., Emblicanin A and B), which stabilize it. It also contains a high concentration of other polyphenols, including ellagic acid, gallic acid, quercetin, kaempferol, phyllemblin, and various tannins and flavonoids (Scartezzini *et al.*, 2006).

Amla's high polyphenol and Vitamin C content provides powerful protection against oxidative stress, which can damage hair follicle cells. Traditional belief holds that Amla nourishes and strengthens the hair roots. Vitamin C is crucial for collagen synthesis, an important component of the connective tissue surrounding hair follicles. Some studies suggest Amla extract can stimulate the proliferation of dermal papilla cells, which play a critical role in regulating hair growth (Promsawan *et al.*, 2020). Preliminary *in vitro* studies have indicated that certain extracts or compounds from Amla might exhibit inhibitory effects on 5α-reductase. Anti-inflammatory Effects: Polyphenols in Amla possess anti-inflammatory properties.

In vitro studies: Numerous studies confirm the potent antioxidant and free-radical scavenging activity of Amla extracts. Research has shown Amla extract can stimulate proliferation and inhibit apoptosis in human dermal papilla cells. Some evidence for 5αR inhibition exists but needs further confirmation (Fujita *et al.*, 2005).

Animal studies: Studies using animal models to specifically evaluate Amla's effect on hair growth are limited compared to Bhringraj, but some have shown positive effects when used in polyherbal formulations (Purwal *et al.*, 2008).

Human studies: Similar to Bhringraj, robust clinical trials focusing solely on standardized Amla preparations for AGA are scarce. However, a randomized, double-blind, placebo-controlled study evaluated a polyherbal formulation containing Amla, among other ingredients, for telogen effluvium (diffuse hair shedding) and found positive results in reducing hair loss (Rajput, 2020). A recent pilot study explored a serum containing Amla extract for AGA, showing statistically significant improvements in hair density and thickness after 12 weeks compared to placebo, warranting larger studies (Suchonwanit *et al.*, 2023).

Amla is widely consumed as food and medicine and is generally considered very safe. Topical application in oils or hair masks is common. Oral supplements are also popular. Due to its sour taste, it might cause mild acidity in some sensitive individuals when taken orally on an empty stomach.

Ginseng (*Panax ginseng*)

Ginseng root has been a cornerstone of Traditional Chinese Medicine (TCM) and Korean traditional medicine for thousands of years, revered as an adaptogen and panacea for promoting vitality, longevity, and overall health. While not as prominently featured for hair loss as Bhringraj or Amla in Ayurveda, its use for strengthening the body and potentially improving hair condition exists in East Asian traditions.

The primary bioactive constituents of *Panax ginseng* are unique triterpenoid saponins known as ginsenosides (e.g., Rg1, Rb1, Rg3, Rh2, CK). It also contains polysaccharides, peptides, polyacetylenes, and phenolic compounds (Jia & Zhao, 2009).

Ginsenosides, particularly Rg3 and Compound K (CK, a metabolite of Rb1 and Rb2), have been shown to promote the proliferation of human Dermal Papilla Cells (hDPCs) and Outer Root Sheath Cells (hORSCs) and inhibit apoptosis. Ginseng extracts and ginsenosides may promote the transition from telogen to anagen phase and prolong the anagen phase (Choi, 2018). Some studies suggest certain ginsenosides (like Rg3) might inhibit 5αR activity and potentially downregulate androgen receptor expression or signaling in dermal papilla cells (Park *et al.*, 2011). Ginsenosides possess antioxidant properties and can modulate inflammatory responses, protecting follicles from stress. Ginseng is traditionally believed to improve circulation.

In vitro studies: Numerous studies have demonstrated the positive effects of various ginsenosides on cultured hDPCs and hORSCs, showing increased proliferation, reduced apoptosis, and modulation of Growth Factors (like VEGF) and cell cycle regulators (Matsuda *et al.*, 2003). Evidence for 5αR inhibition and androgen receptor modulation by specific ginsenosides like Rg3 also exists (Murata *et al.*, 2012).

Animal studies: Topical application of ginseng extracts or ginsenosides has been shown to promote hair regrowth in mice models where hair loss was induced (e.g., using testosterone or chemotherapy agents). These effects were often linked to an earlier onset and prolonged duration of the anagen phase.

Human studies: Several clinical studies, mostly conducted in Korea, have investigated the efficacy of ginseng for hair loss. A randomized, placebo-controlled study evaluated the effect of Korean red ginseng extract (containing specific ginsenosides) in patients with alopecia areata (an autoimmune condition), showing significantly higher hair regrowth compared to placebo (Oh *et al.*, 2014). Another study investigated a topical herbal complex containing *Panax ginseng* for female pattern hair loss, reporting improvements in hair density (Kim, *et al.*, 2017). While promising, more large-scale, high-quality RCTs specifically targeting AGA with standardized ginseng preparations are needed.

Ginseng is generally safe for short-term use but can interact with certain medications (e.g., warfarin, some antidepressants, diabetes medications) and may cause side effects like insomnia or blood pressure changes in some individuals. It's available as root extracts in capsules, powders, tinctures, and topical formulations.

Green Tea (*Camellia sinensis*)

Green tea, originating from China, is one of the most widely consumed beverages globally, prized for its pleasant taste and numerous health benefits attributed to its antioxidant properties. While not a primary traditional remedy specifically for hair loss, its known antioxidant and potential hormonal effects have led to interest in its application for hair health.

Green tea is rich in polyphenols, primarily catechins. The most abundant and biologically active catechin is Epigallocatechin-3-Gallate (EGCG). Other catechins include Epicatechin (EC), Epigallocatechin (EGC), and Epicatechin Gallate (ECG). Green tea also contains caffeine, theanine, and other flavonoids (Cabrera *et al.*, 2006).

EGCG and other catechins are powerful antioxidants that can neutralize ROS, protecting hair follicle cells from oxidative damage. Several *in vitro* and some *in vivo* studies suggest that EGCG can inhibit type I 5α-reductase activity, potentially reducing DHT levels in the scalp. EGCG has been shown *in vitro* to stimulate human hair follicle growth and prolong the anagen stage, possibly by stimulating dermal papilla cells and inhibiting apoptosis. Green tea catechins possess anti-inflammatory properties (Singh *et al.*, 2011).

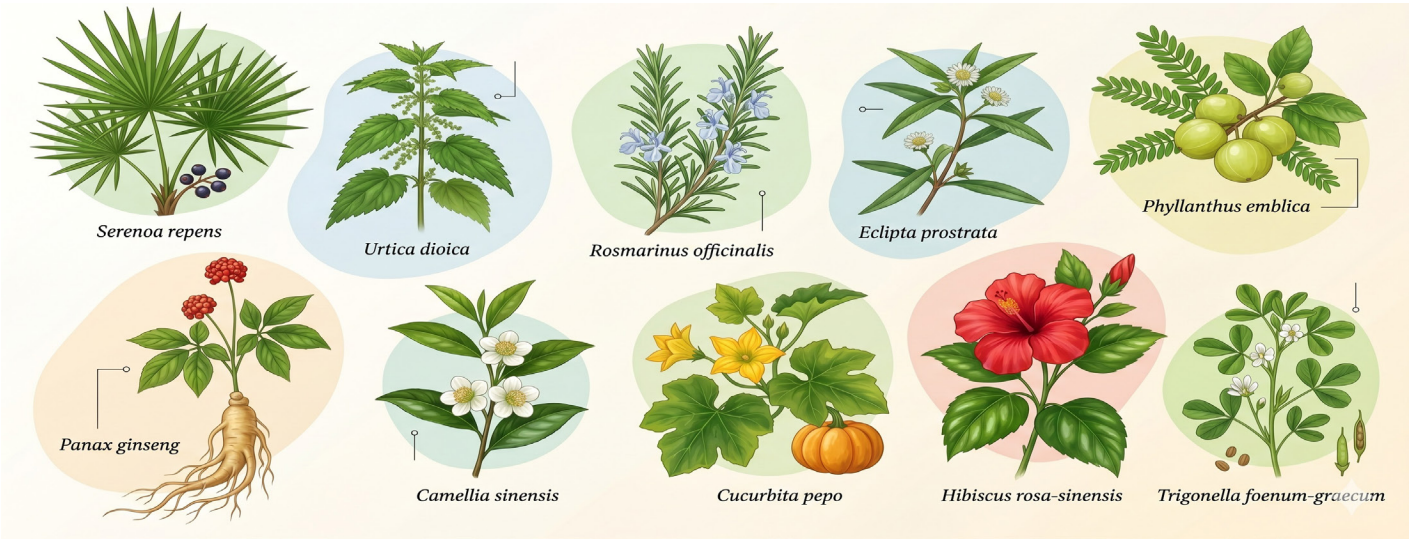

Figure 1: Herbal Plants used in Alopecia Management.

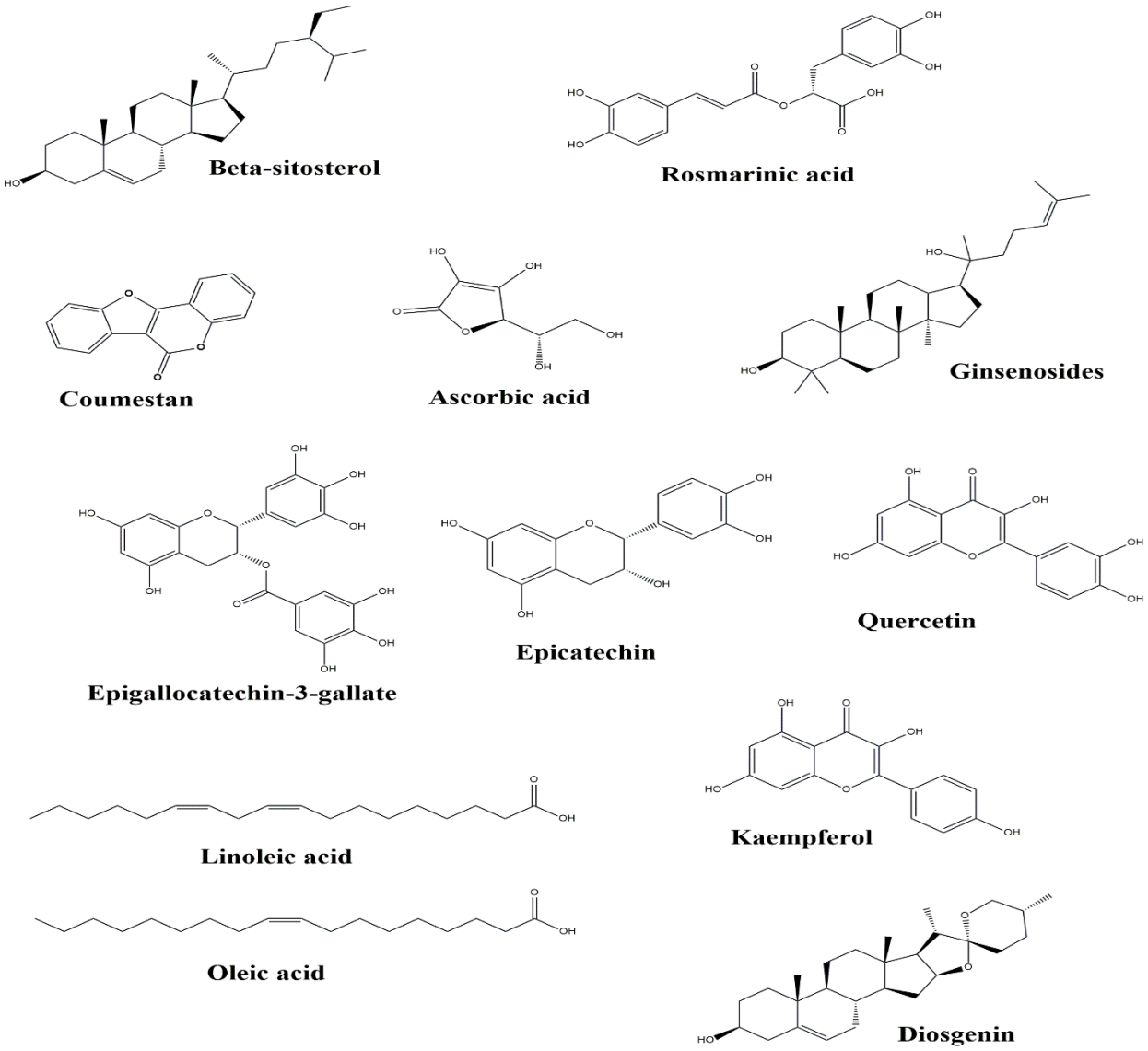

Figure 2: Potential phytoconstituents used in Alopecia Management.

In vitro studies: Studies have demonstrated EGCG's ability to inhibit 5αR (primarily type I) in cultured cells (Hiipakka *et al.*, 2002). Research using cultured human hair follicles showed that EGCG stimulated hair growth, likely mediated via effects on proliferation and apoptosis pathways within the follicle (Kwon *et al.*, 2007). The antioxidant effects are well-established.

Animal studies: Topical application of green tea polyphenols promoted hair regrowth in mice where hair loss was induced by testosterone (Esfandiari & Kelly, 2005). This effect was associated with inhibition of 5αR activity.

Human studies: Clinical evidence specifically for green tea extracts or EGCG for AGA is still limited but emerging. One small pilot study investigating a topical product containing green tea extract among other ingredients reported some positive trends in hair growth (Pazyar *et al.*, 2012). Another study found that supplementation with EGCG fortified with vitamin D showed promise in female pattern hair loss (Hercogova *et al.*, 2020). Many individuals consume green tea regularly, but controlled trials evaluating standardized extracts (oral or topical) solely for AGA are needed to establish clinical efficacy.

Green tea consumption is very safe for most people. Concentrated extracts, especially taken orally on an empty stomach, may cause gastrointestinal upset or, rarely, liver issues in sensitive individuals due to high catechin content. Topical application is generally safe. Available as beverages, capsules/tablets (extracts standardized for EGCG), and in topical hair care products.

Pumpkin Seed Oil (*Cucurbita pepo*)

Pumpkin seeds have been consumed for centuries for nutritional purposes and used in folk medicine, particularly in Eastern Europe and North America, for urinary problems like BPH. Similar to Saw Palmetto, its application for hair loss stems from observations related to BPH and potential effects on androgens.

Pumpkin seeds are rich in unsaturated fatty acids (linoleic, oleic acid), phytosterols (particularly delta-7-sterols, also beta-sitosterol), Vitamin E (tocopherols), carotenoids (lutein), minerals (zinc, magnesium), and cucurbitin (an amino acid) (Dreikorn, 2002).

The primary mechanism proposed is the inhibition of 5α-reductase by phytosterols (like delta-7-sterols and beta-sitosterol) and potentially fatty acids present in the oil, leading to reduced DHT production (Gossell-Williams, 2021). Antioxidant effects from Vitamin E and carotenoids, along with the potential contribution of zinc (essential for hair health), may also play a role.

In vitro studies: Research has shown that pumpkin seed extracts can inhibit 5αR activity (Ejike & Ezeanyika, 2011). The high antioxidant capacity is also documented.

Animal studies: One study in mice found that pumpkin seed oil administration blocked the action of testosterone in promoting prostate growth, partly via 5αR inhibition (Gossell-Williams, 2006). Direct studies on hair growth models are less common but often cited based on the BPH research.

Human studies: A notable randomized, double-blind, placebo-controlled trial specifically investigated the efficacy and tolerability of Pumpkin Seed Oil (PSO) for AGA in men (Cho *et al*., 2014). Seventy-six men with mild to moderate AGA received either 400 mg of PSO per day (in capsules) or a placebo for 24 weeks. The PSO group showed statistically significant increases in mean hair count (around 40% increase) compared to the placebo group (around 10% increase) based on phototrichographic analysis ($p < 0.001$). Self-rated improvement scores were also significantly higher in the PSO group. While this study provides compelling evidence, it had limitations (e.g., the PSO capsule also contained other ingredients from the seed, potential bias in self-assessment). Replication in larger, diverse populations is needed.

Pumpkin seed oil is generally considered safe for consumption and topical use, being a food product. It's available as culinary oil, roasted seeds, and encapsulated oil supplements. Allergies are possible but uncommon.

Hibiscus (*Hibiscus rosa-sinensis*)

The flowers and leaves of the common garden Hibiscus are widely used in tropical regions, including India, in traditional medicine and hair care. Hibiscus flower paste or oil infusions are traditionally applied to stimulate hair growth, prevent premature graying, combat dandruff, and act as a natural conditioner (Nadkarni, 1976).

Hibiscus flowers and leaves contain flavonoids (quercetin, kaempferol glycosides), anthocyanins (in red varieties), mucilage (polysaccharides), vitamins (Vitamin C), amino acids, and traces of alkaloids and terpenoids (Sharma & Bhardwaj, 2014).

The mechanisms are largely based on traditional understanding and preliminary research: Extracts may stimulate hair follicles and potentially prolong the anagen phase. Flavonoids and anthocyanins provide antioxidant protection (Mak *et al*.,2013). Mucilage provides moisturizing and conditioning properties to the hair shaft. Some components may possess mild anti-inflammatory activity.

In vitro studies: Studies have confirmed the antioxidant activity of Hibiscus extracts. Research directly on hair follicle cells is limited.

Animal studies: Several studies in rats and mice provide support for the traditional claims. Topical application of petroleum ether extracts of *Hibiscus rosa-sinensis* leaves and flowers demonstrated significant hair growth-promoting activity, sometimes comparable or superior to minoxidil or finasteride in the specific models used (Adhirajan, 2003, Garg & Paliwal, 2011). These studies often showed an increase in the number of follicles in the anagen phase and larger follicle size.

Human studies: Despite strong traditional use and positive animal data, well-controlled clinical trials evaluating standardized Hibiscus preparations for alopecia in humans are lacking. Its use remains primarily based on traditional practice and anecdotal reports, often incorporated into herbal hair oils and masks.

Hibiscus flowers and leaves are generally considered safe for topical use and consumption (e.g., hibiscus tea). Allergic reactions are possible. Available as fresh/dried flowers/leaves, powders, and infused oils.

Fenugreek (*Trigonella foenum-graecum*)

Fenugreek seeds have a long history of use in culinary traditions (especially Indian) and traditional medicine (Ayurveda, TCM) for various purposes, including improving digestion, managing blood sugar, increasing milk production in lactating women, and as a remedy for hair problems (Basch *et al*., 2003). Soaked seeds or paste are traditionally applied to the scalp to reduce hair fall, promote growth, and treat dandruff (Goyal *et al*., 2021).

Fenugreek seeds are rich in protein, soluble fiber (galactomannans), steroidal saponins (diosgenin, yamogenin, tigogenin), alkaloids (trigonelline), flavonoids (quercetin, luteolin), free amino acids (4-hydroxyisoleucine), vitamins, and minerals (Nagulapalli Venkata *et al*., 2017).

Diosgenin is a precursor for steroid synthesis and may have estrogen-like effects or potentially modulate androgen pathways, although evidence for direct 5αR inhibition is weak. Nicotinic acid (metabolite of trigonelline) and flavonoids may improve scalp circulation and exert anti-inflammatory and antioxidant effects. High protein and amino acid content might provide building blocks for hair structure. Lecithin (a phospholipid) acts as an emollient. Traditional belief suggests direct stimulation of hair growth.

In vitro studies: Studies have confirmed antioxidant and anti-inflammatory properties of Fenugreek extracts. Research on direct effects on hair follicle cells or 5αR inhibition is limited.

Animal studies: Some studies using animal models have shown that fenugreek seed extracts can promote hair growth, potentially linked to improved circulation or hormonal modulation (Sreeja *et al.*, 2021).

Human studies: Clinical evidence is sparse but includes a few studies, often using specific proprietary extracts or formulations. A small, randomized, double-blind, placebo-controlled study investigated the effect of an oral supplement containing fenugreek extract (along with other minerals) in healthy women with self-perceived thinning hair (Beguin, 2004). The active group reported significant improvements in hair thickness and density compared to placebo after 6 months. Another study evaluated a topical lotion containing fenugreek extract for hair loss, also reporting positive subjective results (Soltani *et al.*, 2016). However, larger, independent trials using standardized extracts are necessary.

Fenugreek seeds are generally safe when consumed in amounts typically used in food. Supplements or large doses may cause gastrointestinal upset or a maple syrup-like body odor. Due to potential uterine-stimulating effects, high doses should be avoided during pregnancy. Topical application as a paste or in hair products is common. Available as whole/ground seeds, capsules, and in topical preparations.

FUTURE DIRECTIONS / RESEARCH GAPS

The primary research gap identified is the lack of high-quality, large-scale clinical trials for many traditional herbs like Bhringraj, Amla, and Hibiscus, which currently rely heavily on anecdotal evidence or animal data. Future research must focus on the standardization of phytochemical extracts to address the challenges of consistent potency. Furthermore, while some herbs show promise comparable to minoxidil or finasteride, independent and diverse population studies are necessary to validate these claims globally.

CONCLUSION

The exploration of herbal remedies for alopecia reveals a rich tapestry of traditional knowledge partially substantiated by modern scientific investigation. Plants like Saw Palmetto, Rosemary, and Pumpkin Seed Oil show particular promise for AGA, backed by *in vitro* mechanistic studies (often 5αR inhibition) and encouraging, albeit sometimes preliminary, human clinical trial data. Ginseng and Green Tea offer plausible mechanisms involving hair follicle cell stimulation, antioxidant effects, and potential hormonal modulation, supported by *in vitro* and animal data, with emerging human evidence. Herbs deeply rooted in Ayurvedic tradition, such as Bhringraj, Amla, and Hibiscus, demonstrate compelling results in animal models promoting hair growth and improving hair cycle parameters, likely through direct follicular stimulation and potent antioxidant actions, although rigorous human trials are largely missing. Stinging Nettle and Fenugreek are also popular ingredients, potentially contributing via anti-inflammatory actions, nutrient supply, or weaker hormonal effects, but require more dedicated clinical research for alopecia. Common threads among these botanicals include multi-target potential addressing not only the hormonal aspect (DHT) but also oxidative stress, inflammation, and potentially scalp microcirculation. This contrasts with the often single-target approach of pharmaceuticals like finasteride. However, this phytochemical complexity also presents challenges in standardization and ensuring consistent potency of herbal products.

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ABBREVIATIONS

ADME: Absorption, Distribution, Metabolism, And Excretion; **AGA:** Androgenetic Alopecia; **DHT:** Dihydrotestosterone; **FDA:** Food And Drug Administration; **BPH:** Benign Prostatic Hyperplasia; **SHBG:** Sex Hormone-Binding Globulin; **NF:** Nuclear Factor (commonly Nuclear Factor-Kappa B, NF-κB); **ROS:** Reactive Oxygen Species; **TCM:** Traditional Chinese Medicine; **PSO:** Pumpkin Seed Oil; **VEGF:** Vascular Endothelial Growth Factor; **EGCG:** Epigallocatechin Gallate; **SPET:** Single Photon Emission Tomography.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

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AUTHOR CONTRIBUTIONS

SK and GP were responsible for the study design and manuscript drafting. JC, DG, and RH performed the literature review and data extraction. CT, RM, and AS reviewed and edited the manuscript for intellectual content.

SUMMARY

The review article comprehensively explores Androgenetic Alopecia (AGA), the most common form of hair loss, and evaluates the potential of ten herbal plants as alternative treatments. The review highlights the limitations and side effects of conventional

FDA-approved treatments like minoxidil and finasteride, propelling interest in herbal remedies rich in phytochemicals that may inhibit 5-alpha-reductase, reduce inflammation and oxidative stress, improve scalp circulation, and stimulate hair follicles. The ten plants reviewed are Saw Palmetto, Stinging Nettle, Rosemary, Bhringraj, Amla, Ginseng, Green Tea, Pumpkin Seed Oil, Hibiscus, and Fenugreek. Each is discussed regarding traditional uses, key phytochemicals, proposed mechanisms of action, and evidence from *in vitro*, animal, and human studies. For example, Saw Palmetto and Pumpkin Seed Oil exhibit promising 5-alpha-reductase inhibition and clinical effects comparable to pharmacological treatments. Rosemary oil shows efficacy similar to minoxidil in human trials, with fewer side effects. Other herbs like Bhringraj, Amla, and Hibiscus demonstrate strong antioxidant and hair growth-promoting properties in animal models but lack robust human trials. Stinging Nettle and Fenugreek may support hair health through anti-inflammatory and nutritional effects but require more focused clinical research. Overall, the review emphasizes herbal medicines' multi-target potential addressing hormonal, inflammatory, oxidative, and circulatory factors involved in AGA. While several herbal options hold promise, the authors caution that current evidence is limited by small-scale studies and variability in formulations, underscoring the need for larger, rigorous clinical trials and professional consultation for personalized care. The article concludes that herbal remedies offer a valuable complementary approach in alopecia management, bridging traditional knowledge and emerging scientific validation.

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