



A Role Of Coffee Bioactive Caffeine In Hair Growth And Hair Loss Control: A Review

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ABSTRACT

Coffee, a well known processed beverages globally and Arabica coffee [*coffea arabica* L.] is one of the most popular coffees. Coffee beans are rich in bioactive compounds such as caffeine, chlorogenic acids, flavonoids, polyphenols such as caffeoylquinic acids [CQAs] and diterpenes. Recent studies has highlighted its potential role in promoting hair growth and preventing hair loss. This review explores the mechanisms of coffee bioactives, specially caffeine, it helps in stimulating hair follicles, enhancing the hair cycle anagen phase, and counteracting androgenic alopecia. The article discusses the formulation strategies, cosmetic applications, safety considerations, and regulatory aspects. The review aims to how coffee derived ingredients are used in hair care and their potential expansion into other cosmetic applications. It acts as a psychoactive stimulant, increasing cognition and awareness while suppressing fatigue. Caffeine is being widely utilised in the food, pharmaceutic, and cosmetics industries due to its multifaceted properties. It is an alkaloid of interest for the pharmaceutical industry because of its stimulating properties on the nervous and cardiovascular systems .It acts as a psychoactive stimulant, increasing cognition and awareness.

Keywords - Coffee Bioactives, *Coffea arabica*, hair loss and hair growth, coffee extract, caffeine, skin penetration, cosmetics.

I.INTRODUCTION

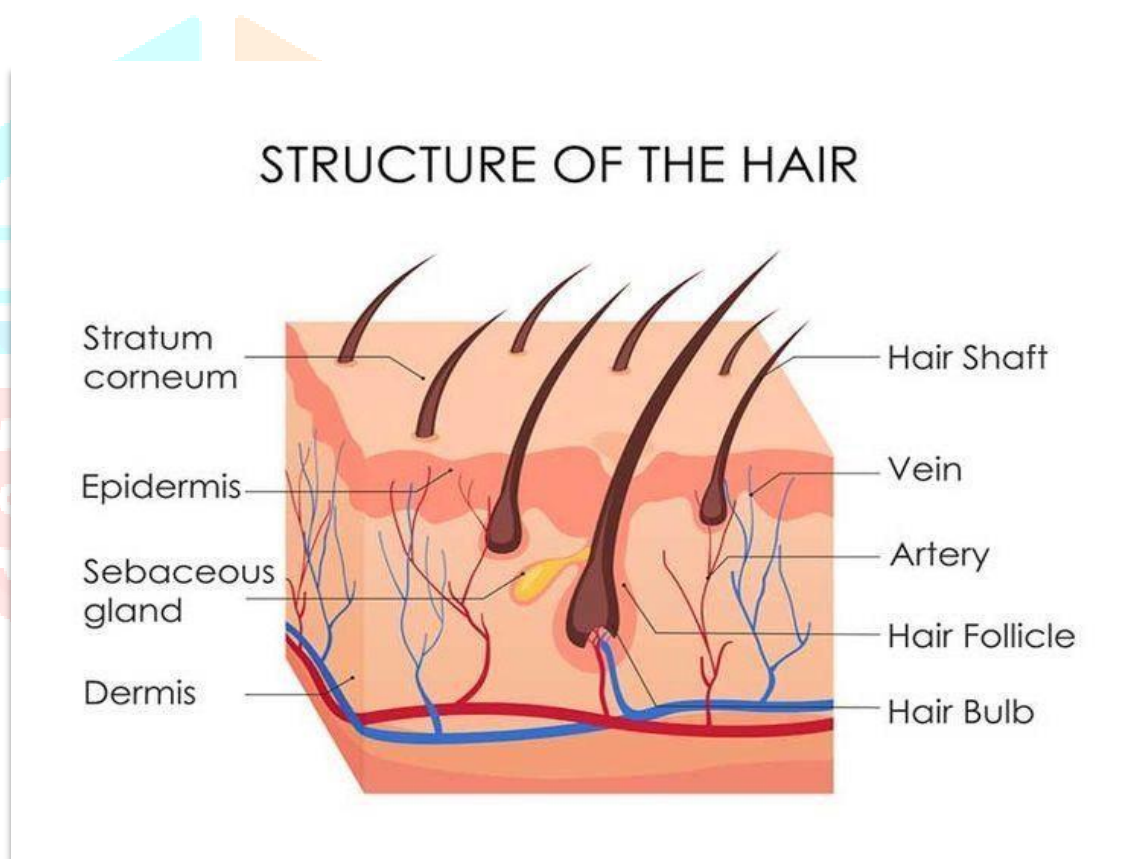
Coffee (*Coffea arabica*) is rich in pharmacologically active compounds. Caffeine has a high potential to be beneficial in subjects suffering from hair loss that originates from premature termination of the hair growth phase. caffeine is the most studied for its ability to stimulate hair follicles and improve scalp health and hair growth. Bioactive compounds present in coffee are Caffeine, chlorogenic acid, flavonoids and polyphenols, diterpenes. These compounds contribute to hair growth and scalp health. Caffeine readily forms bonds with water and other molecules which may influence its bio availability, hair follicles seem to be both a main entry route into the skin and target structures for caffeine at the same time. Caffeine is considered an active molecule in various contexts most probably as central nervous system [CNS] stimulant. Caffeine topical application or use has potential in modulating hair follicles dynamics and the mechanisms of hair loss. The study suggest that coffee bioactives can perform stimulate hair follicle activity, protects follicles from hormonal damage, and also improves blood circulation in hair scalp.

The most relevant type of Hair loss is androgenetic alopecia [AGA].it affects at least 50 percent of men by the age of 50. AGA is heritable, androgen-dependent and occurs in defined pattern. In this review both types of hair loss are referred to as AGA and it is common affecting both men and women. The demand for natural and plant-based alternatives has led to increased interest in herbal and bioactive ingredients. Nutrition is a factor affecting the health and appearance of hair.

Hair is an appendage of the skin that grows out of an organ known as the hair follicle. A hair is made up of follicle that is tube like organ in the under layer of dermis and linked to body's blood supply, Root portion of hair below the skin, embedded in the follicle , Papilla indentation of follicle where blood vessels, nerves enter and exit, Matrix is area of cell division and hair growth. The bioactive compounds in coffee pulp extracts including phenolic compounds, flavonoid compounds, and caffeine were reported in the previous study

Each hair has a hair shaft and hair root, the shaft is the visible part of the hair that sticks out of the skin, new hair cells are constantly being made in the hair bulb, close to the papilla.

Sebaceous glands are oil glands in the skin that connected to hair follicles; secretes sebum [fatty, oily substance]



The growth and loss of hair may seem like a simple process, but the hair growth cycle is composed of three distinct phases, these stages of hair growth have been studied in depth to better understand how hair growth and what to be done to prevent hair loss. The three phases- anagen, catagen, and telogen covers the growth and maturation of hair and activity of the hair follicle that produce individual hairs. Each phase has a timeline which can be affected by age, nutrition, and overall health.

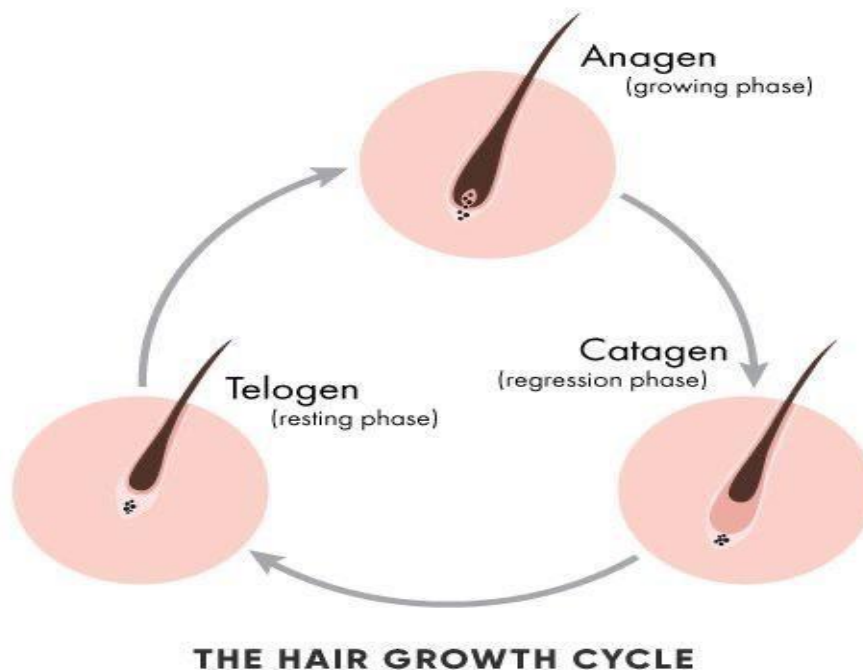
Hair Growth Cycle

Hair growth occurs in three phases:

Anagen (growing phase)

Catagen (transition phase)

Telogen (resting phase)



II. Mechanisms of Coffee Bioactives in Hair Growth

Coffee is more than just a morning pick-up ; it contains potent actives that interact directly with hair follicles. Hair growth cycle depend on signaling pathways from the surrounding cellular microenvironment including cell-to-cell interactions, hormones, and cytokines. numerous growth factors including vascular endothelial growth factor [VEGF], fibroblast growth factor [FGS]-5S, and insulin-like growth factor [IGF]-1, play pivotal roles in the regeneration of hair shaft. Available data suggest that the caffeine penetrates in human HF's within minutes and can remain there for up to 48hrs. It has been reported that potassium ion channels have a significant role in stimulating hair growth, particularly in boosting the growth of HFDPCs by opening potassium ion channels that affect hair follicles and encourage hair growth.

Caffeine inhibits the enzyme phosphodiesterase [PDE] which results in an increase in cyclic adenosine monophosphate [cAMP]. cyclic adenosine monophosphate stimulates cell metabolism and cell proliferation. Caffeine also prolongs duration of anagen phase by stimulating the proliferation of the hair matrix keratinocytes and increasing the expression of IGF-1 gene. Chlorogenic acid antioxidant present in coffee influence hair upregulation of IGF1, KGF, and VEGF genes, which enhanced epithelial cells and keratinocytes in hair. A coffee pulp extract with high caffeine [1.9percent dry weight], flavonoid [0.7percent], and phenolic content [0.6] show high antioxidant activity and increased cell viability and migration of human hair follicle dermal papilla cells in an in vitro experiment .

- Stimulation of Hair Follicle Cells
 - Promotes keratinocyte proliferation
 - Enhances hair shaft elongation
 - Increases follicle size
 - Coffee contains polyphenols that:
 - Reduce oxidative stress
 - Protect hair follicles from damage
- Studies show:

- o Increased hair follicle o Prolongation of anagen phase o Improved blood circulation in scalp o hair loss

III. FORMULATION OF HAIR SERUM

INGREDIENT	QUANTITY	THEIR ROLE
Caffeine extract \ coffee extract	0.7ml	Active ingredient
Glycerine	6ml	Soothing and moisturizing agent
Propylene glycol	5ml	Penetration enhancer
Distilled water	To 100ml	Solvent
Carbopol 940	0.5g	Gelling agent
Triethanolamine	0.3	Ph adjustment
Phenoxyethanol	0.6	Prevents microbial growth
Coffee essential oil	Few drops	Fragrance

Procedure :

In clean mortar pestle take Carbopol to disperse with warm distilled water for swelling the gel then add glycerine, keep it for 30 minutes.

Add TEA then stir it slowly until completely dissolved and gel forms, then add PG, preservative and coffee extract to the solution.

Mix thoroughly to uniform distribution ,add the essential oil.

IV. SAFETY AND REGULATORY ASPECTS :

Coffee and its bioactives components are safe for topical application in cosmetics caffeine readily forms bonds with water and other molecules which influence its bioavailability and should be taken into hair products. The metabolic activity of caffeine and its ability to enter and accumulate in the hair follicles combined with the results of available clinal trials indicates that caffeine could indeed prove as an effective and safe option in the management of hair loss and hair growth. However in some individuals, mild adverse effects may occur such as dryness in scalp, scalp irritation generally in cases of sensitive skin or exposure. These reactions are mild and if occur discontinue the product so they are broadly well tolerated when appropriately formulated. They are permitted under regulatory frameworks including Bureau of Indian standards [BIS] in India. They ensures that by setting mandatory standards [IS] for ingredients, manufacturing practices, finished products safety under the drug and cosmetic Act. Also products manufactured or sold in India meet high safety, quality, and performance through standardization, certification and hallmarking. Overall, regulatory approval and favorable safety of coffee bioactives support continued use and growing popularity in cosmetic and hair care applications.

V. EVALUATION PARAMETERS :

Evaluating the efficacy of coffee bioactives primarily caffeine, chlorogenic acids [CGAs], and polyphenols requires assessment phytochemicals stability to clinical hair growth metrics. Total phenolic content [TPC] and total flavonoids content [TFC] measures by folin-ciocalteu assay and aluminium chloride colorimetric assay for antioxidants. DPPH and ABTS for oxidative stress hair follicle aging. HPLC used to measures concentration [0.2percent for topical and 1percent on shampoos and others].

How coffee helps hairs:

Check on people: gently pulls a section of hair to see how many strands fall out, measuring the diameters of individuals hairs, checking how many hairs growing vs. how many resting.

Coffee extract strong enough to work: caffeine levels, measures how extract can protect cells from damage, their stability.

Evaluation of Growth signals checking anagen phase, growth factor measuring of IGF-1 [insulin growth factor] and VEGF vascular endothelial growth factor energy boost caffeine blocks certain enzymes that slows down hair growth measures if cells have energy to build hairs, scalp health too oily or too dry , strength of the hairs, softness coffee can be harsh or acidic, sebum levels, hair density number of hair per cm².

VI. DISCUSSION

Coffee bioactives, particularly caffeine, have demonstrated strong potential in promoting hair growth mechanisms. Caffeine is known for enhancing vasodilation, thereby improving blood circulation, the scalp improving and nutrient delivery to hair follicles. It also stimulates follicular activity effects of dihydrotestosterone (DHT), which affects androgenic alopecia.coffee-derived compounds serve as effective natural alternatives in hair care formulations. However, despite these promising findings, several limitations remain. there is a lack of extensive clinical trials involving human subjects to validate efficacy and safety on a larger scale. Another important challenge is the lack of standardization in formulations, including variations in concentration, extraction methods, and delivery systems, which can influence the overall effectiveness of coffee-based products.

VII. CONCLUSION

Coffee bioactives offer a promising and natural approach for promoting hair growth and preventing hair loss, making them highly valuable in the development of modern cosmeceutical products. Caffeine is a molecule with multifaceted effects observed at molecular, cellular and clinical level. Caffeine interacts with adenosine pathway leading to increased CAMP levels and also acts as an antioxidant. The clinical studies burdened with methodological flaws, also effectiveness of caffeine which places the molecule among promising hair loss remedies. Caffeine stimulating hair follicles, enhancing scalp blood circulation, and reducing the negative impact of hormonal factors such as DHT. The combined antioxidant and anti-inflammatory properties of other coffee compounds support scalp health and hair regeneration.. Future research should focus on conducting well-designed clinical trials, , and ensuring standardization of

formulations for consistent results. coffee bioactives have the potential to become a key ingredient in safe, effective, and natural hair growth therapies.

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