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Herbal insights into melanin synthesis: Enhancing hair health naturally

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Abstract

Melanin, a natural pigment found in many organisms, determines skin, hair, and eye colour and protects against UV radiation. In hair, melanin is synthesized by melanocytes through melanogenesis, involving several enzymatic steps. There are different types of melanin: eumelanin, which provides darker hair tones and stronger UV protection, and pheomelanin, which is found in lighter hair and offers less UV resistance, making it more vulnerable to oxidative stress. Reduced melanin production over time causes hair to grey with age. Beyond colour, melanin supports scalp and hair health, influencing hair growth and vitality, making it crucial for both aesthetic and protective roles in human hair biology.

Keywords: Melanin, UV damage and radiation, Hair aging etc.

Introduction

The majority of creatures, including humans, contain the complex natural pigment known as melanin. It is available in various forms, each with unique properties and functions, and it performs a number of significant duties. This is a thorough explanation of melanin, including its varieties, purposes, and definition^[1].

Melanin: What Is It?

Melanocytes are cells that create the pigment known as melanin. In humans and other animals, it is in charge of determining the colour of their skin, hair, and eyes. Other tissues, such as the brain and inner ear, also contain melanin^[2].

Hair colour and condition are mostly determined by melanin. Its utility goes beyond merely giving natural hair colour; it also affects other hair treatments, emerging technology, and possible uses in the future^[3].

The production of hair is not directly influenced by melanin. Rather, its main function is to determine hair colour^[4]. On the other hand, melanin and the melanocytes that create it may indirectly affect the general condition of the scalp and hair, which may then affect the formation of new hair^[5].

Another essential biological function of melanin in hair, according to professional hairstylist Nikki Goddard, an associate degree holder in cosmetology, is that it shields hair from UV brightness and sun rays (Photoprotection).

"The type and concentration of melanin determine the latter". For example, due to eumelanin's stronger photostability than pheomelanin, dark hair is more resistant to UV radiation and deterioration than light hair^[6].

Melanin Synthesis^[7]

Melanocytes are specialised cells that are involved in the creation of melanin, a process known as melanogenesis. The skin, hair follicles, and eyes are among the body parts that contain these cells. Melanogenesis is a multi-step process that requires multiple essential enzymes. This is a synopsis:

Steps in Melanin Synthesis:

- **Tyrosine Uptake:** Tyrosine is an amino acid that is taken up by melanocytes from the circulation.
- **Tyrosine to Dopaquinone:** Tyrosine is hydroxylated to L-DOPA (3,4-dihydroxyphenylalanine) by the enzyme tyrosinase, which then oxidises L-DOPA to dopaquinone.

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Dopaquinone Route

- **The Synthesis of Eumelanin:** Dopaquinone is converted to dopachrome, which is then subjected to additional oxidation and polymerisation procedures.

- **Pheomelanin Synthesis:** Dopaquinone can also create cysteinyl-DOPA in the presence of cysteine, and this intermediate product is subsequently transformed into pheomelanin, a yellow to red pigment.

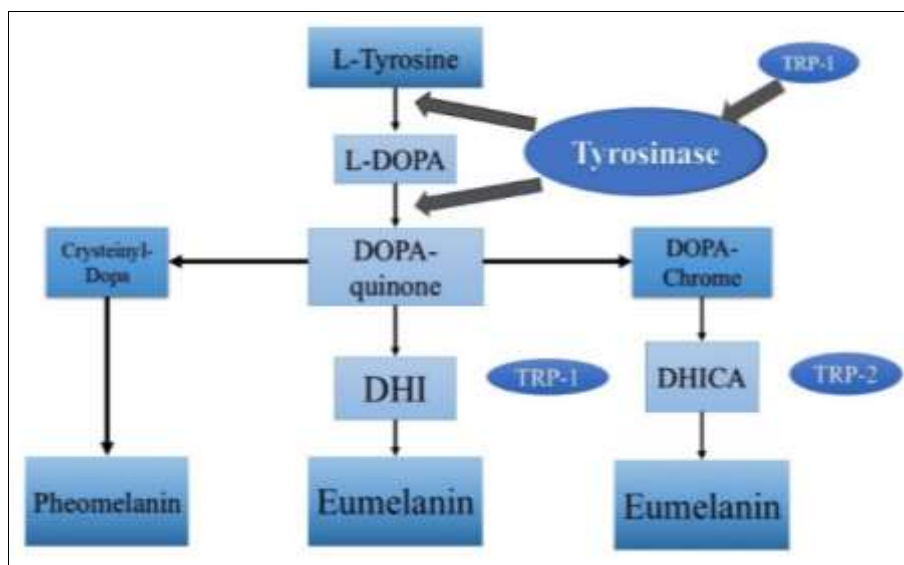


Fig 1: Synthesis of melanin

Role of Melanin in Hair

Hair Colour^[8]

- **Eumelanin:** This kind of melanin gives hair its dark brown to black hues. The distribution and quantity of eumelanin define the colour of hair, either brown or black.
- **Phenomenelanin:** This kind of melanin gives hair its red and yellow tones. People with red hair or blonde hues have this because pheomelanin is present.
- **Distribution of Melanin:** The range of hair colours is determined by the density and ratio of pheomelanin to eumelanin in the hair shaft.

Hair Aging^[9]

Greying hair is caused by a decline in melanin production as we age. Hair loses colour as a result of a reduction in melanocyte activity, which causes melanin to be lost.

UV Damage and Radiation^[10]

Phenomenelanin

- Less Protection:** Compared to eumelanin, phenomenelanin offers less protection from UV radiation. Individuals who have greater skin and hair pheomelanin levels are generally more vulnerable to UV radiation and have a higher chance of developing skin cancer.
- Oxidative Stress:** When phenolomelanin is exposed to UV light, it can produce free radicals, which can cause oxidative stress and damage to skin and hair cells.

Eumelanin

- Slower Lightening Process:** When exposed to sunlight, hair with a higher eumelanin content lightens more slowly than hair with a lower eumelanin content. Eumelanin is more resilient to UV-induced deterioration, which explains this.
- Less Oxidative damage:** UV exposure-induced oxidative damage is lessened by eumelanin. Hair damage from oxidative stress can include colour loss and structural weakness.

2. Herbs used for improving melanin synthesis

Almond

Biological Source: It consists of seeds of *Prunus amygdalus*. (*Amygdalus communis*) and/or *Prunus amygdalus* var. Amara (bitter almond) or mixture of both belonging to family Rosaceae^[11].

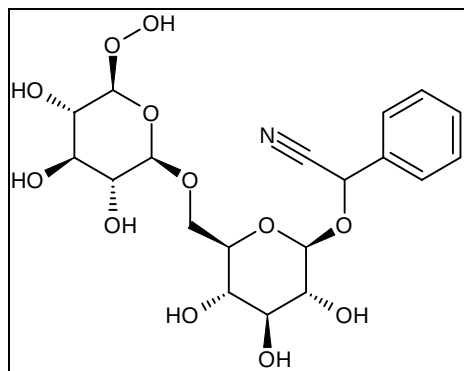


Fig 2: *Prunus dulcis* (Almond)

Phytoconstituents: The main phytoconstituents of almond are fixed oil, proteins, and mucilage. The fixed oil contains majorly unsaturated fatty acid such as linolenic acid and the bitter almonds additionally contain amygdalin^[12].

Chemical Constituents^[13]

- Flavonols
- Proteins
- Vitamins
- Glycoside



Amygdalin

Mode of action

Nutrient-dense foods like almonds may help maintain the health of hair by assisting in the manufacture of melanin, which is essential for pigmentation. The following almond constituents could support these advantages:

Vitamin E (Tocopherol) ^[14]

- **Role in Hair Growth:** It is a potent antioxidant that shields hair follicles from oxidative stress, which can cause hair loss and damage. Additionally, it encourages healthy scalp circulation, which supplies vital nutrients to the roots of hair.
- **Melanin Synthesis:** Vitamin E functions as an antioxidant and may help shield melanocytes, or the cells that make melanin, from oxidative damage. This could help preserve natural hair colour and delay the onset of premature greying.

Vitamin B7 (Biotin) ^[15]

- **Role in Hair Growth:** Biotin is necessary for the synthesis of keratin, a protein that gives hair its structure. Sufficient amounts of biotin are associated with less hair loss and better-looking hair growth.
- **Melanin Synthesis:** Although biotin doesn't directly effect the synthesis of melanin, a lack of it can cause brittle hair and hair loss, which can alter the colour and appearance of hair.

Use: Almond is used for hair growth promoting activity ^[13].

Amla

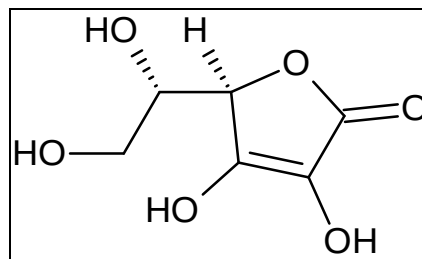
Biological Source: It consists of dried as well as fresh fruits of the plant *Emblia officinalis* Gaerth *Phyllanthus emblica* Linn. belonging to family Euphorbiaceae ^[11].

Fig 3: *Phyllanthus emblica* (Amla)

Phytoconstituents: Amla fruit is a rich natural source of vitamin c (Ascorbic acid) and contain 600- 700 mg per 100 g of the fresh pulp. Furthermore, fruits also contain about 0.5 per cent fat, phyllembin and 5 percent tannis ^[11].

Chemical constituents ^[13]

- Essential Oil
- Tannin
- Gum
- Alkaloids
- Albumin



L-Ascorbic acid (Vitamin C)

Mode of action ^[16]

- Strong antioxidants like vitamin C work to scavenge free radicals, which are unstable chemicals that can harm cells including those that are essential for melanin synthesis and hair growth. Vitamin C may shield hair follicles and melanocytes-the cells that produce melanin from harm by lowering oxidative stress, therefore promoting normal hair growth and colouration.

Use: It is used in hair problems such as premature ageing, greying of hair, hair fall and damage ^[13].

Ashwagandha

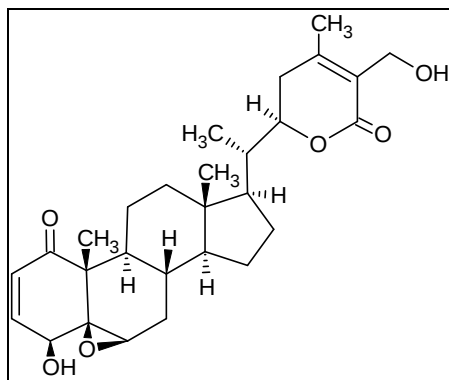
Biological Source: It consists of the dried roots and stem bases of *Withania somnifera* Dunal, belonging to family Solanaceae ^[11].

Fig 4: *Withania somnifera* (Ashwagandha)

Phytoconstituents: Ashwagandha contains a variety of phytoconstituents such as Withanolides, somniferine and pseudowithanine ^[17].

Chemical Constituents ^[18]

- Alkaloid
- Flavonoids
- Steroids
- Saponins



Withanolides

Mode of action

Traditional Ayurvedic medicine uses ashwagandha, an adaptogenic plant, for a variety of health advantages, including hair growth. Its precise mode of action is unclear, nevertheless, especially with respect to melanin synthesis and hair development. Here are a few possible ways that ashwagandha could affect these functions^[19].

- **Antioxidant Activity:** Withanolides, which have strong antioxidant qualities, are abundant in ashwagandha. By lowering oxidative stress in hair follicles, these antioxidants may be able to stop damage and encourage healthy hair development. Greying and hair loss have been related to oxidative stress^[20].
- **Hormonal Balance:** It is well known that ashwagandha affects hormone levels, especially thyroid and cortisol. Stress-related hair loss may be lessened by ashwagandha, which lowers the stress hormone cortisol. Hair growth depends on healthy thyroid function; therefore ashwagandha's ability to support thyroid function may also indirectly aid hair health^[21].
- **Melanin Production:** The pigment that gives hair its colour, melanin, is produced in response to a number of variables, including oxidative stress and hormonal abnormalities. Although there isn't any concrete proof that ashwagandha directly boosts melanin synthesis, it's hormone-balancing and antioxidant qualities might help keep hair colour vibrant and delay the onset of greying^[22].

Use: Ashwagandha is commonly used in traditional medicine and modern wellness practices for hair growth and potentially supporting melanin synthesis^[23].

Bhringaraj

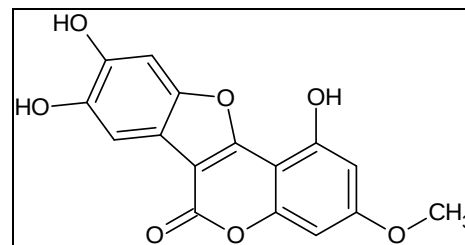
Biological Source: It consists of whole plant botanically known as *Eclipta alba* belonging to family Asteraceae^[11].

Fig 5: *Eclipta alba* (Bhringaraj)

Phytoconstituents: The main chemical constituent of Bhringaraja (*Eclipta prostrata*), commonly known as false daisy, which is often associated with promoting hair growth, is Wedelolactone^[24].

Chemical constituents^[13]

- steroidal alkaloids
- flavonoids, phenolic acids



Wedelolactone

Mode of action

The plant is said to have the ability to promote melanin synthesis, which aids in retaining natural hair colour, and to encourage hair growth^[25].

Use: It is used for blanking and strengthening of the hairs^[13].

Bibhitaki

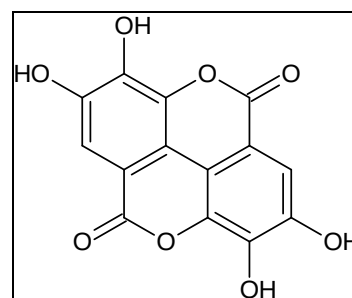
Biological source: It consists of fruits and leaves of *Terminalia bellirica* belonging to family Combretaceae^[26].

Fig 6: *Terminalia bellirica* (Bibhitaki)

Phytoconstituents: The main phytoconstituents in Bibhitaki that are thought to contribute to hair growth include: Tannin Compounds, Gallic Acid, Ellagic Acid, Saponins^[27].

Chemical constituents^[28]

- Flavonoids
- Glycosides
- Fatty acids
- Saponins



Ellagic acid

Mode of action

- **Antioxidant Action:** Flavonoids and phenolic substances found in bibhitaki aid in the fight against oxidative stress. These antioxidants shield hair follicles from harm and promote a healthy environment for hair growth by minimising the harm that free radicals inflict^[29].
- **Anti-inflammatory Properties:** Because of the herb's anti-inflammatory properties, hair follicle blood circulation can be improved by relieving scalp irritation and inflammation. Better oxygen and nutrient supply to the hair roots results from improved circulation, which supports healthy hair development^[30].
- **Nourishing the Scalp:** Saponins found in bibhitaki have purifying qualities that aid in clearing the scalp of pollutants. Having a clean, healthy scalp is essential for the best possible hair development^[31].
- **Strengthening Hair Roots:** Bibhitaki's tannins have astringent qualities that can strengthen and tighten hair roots, preventing hair loss and enhancing general hair health^[32].
- **Improving Hair Follicle Health:** Bibhitaki's blend of minerals, anti-inflammatory agents, and antioxidants can support the preservation of hair follicle health, which is necessary for the development of robust, healthy hair^[33].

Use: It is helpful for hair problems such as dandruff, itching, loss of hair, and folliculitis.

Bibhitaki benefits the hair by strengthening them from the roots to the bottom. It provides essential nutrients to the follicles so that hair remains healthy, black, and strong^[34].

Black sesame seed

Biological source: It consists of seeds of *Sesamum indicum* belonging to family Pedaliaceae^[11].

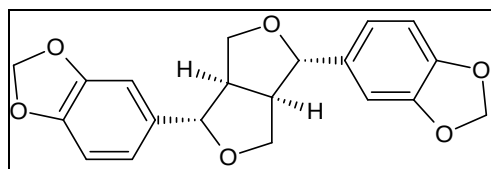


Fig 7: Sesamum (Black sesame seed)

Phytoconstituents: The main chemical constituent of black sesame seeds that is often associated with hair growth is sesamin^[35].

Chemical constituents^[36]

- Lignans
- Fatty acids
- Phytosterols
- Tocopherols



Sesamin

Mode of action

Traditional medicine holds black sesame seeds (*Sesamum indicum*) in high regard due to their possible advantages in bolstering melanin synthesis and enhancing hair health. The following are the main pathways by which black sesame seeds may affect the production of melanin and hair development^[37].

Use: They contain nutrients that nourish your scalp and promote healthy hair growth^[38].

Coconut oil

Biological Source: It consists of dried kernels of the *Cocos nucifera* belonging to family Palmae^[11].

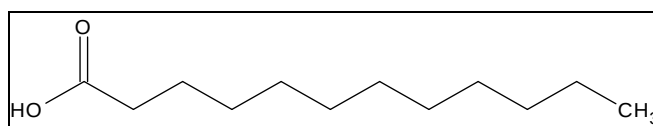


Fig 8: *Cocos nucifera* (Coconut oil)

Phytoconstituents: The main phytoconstituent in coconut oil is Lauric acid^[39].

Chemical constituents^[13]

- Phenols
- Tannins
- Flavonoids
- Steroids
- Alkaloids



Lauric acid

Mode of action

Coconut oil's mechanism of action for promoting hair growth involves several factors:

Penetration into the Hair Shaft

- **Lauric Acid:** The main fatty acid in coconut oil, lauric acid, has a low molecular weight and a straight chain structure. This enables it to permeate the hair shaft more thoroughly than other oils. Lauric acid enters the hair cortex and helps to reduce protein loss, strengthen the hair, and prevent damage, all of which are necessary for maintaining hair health and growth^[40].
- **Moisturization and Lubrication:** Coconut oil serves as a natural moisturiser and conditioner. It helps to keep moisture in the hair, preventing it from becoming dry and brittle. Well-hydrated hair is less likely to break, which can lead to longer, healthier hair^[41].
- **Antimicrobial and Antifungal Properties:** Coconut oil

contains fatty acids with antibacterial and antifungal effects, including lauric acid and capric acid. These can help keep your scalp healthy by preventing infections and dandruff, which can stunt hair development or cause hair loss^[42].

- **Anti-Inflammatory Effects:** Coconut oil has anti-inflammatory properties that can soothe the scalp, reducing inflammation and irritation. A healthy scalp environment is crucial for optimal hair growth^[43].

Use: Coconut oil is used to prevent hair loss^[13].

Curry leaves

Biological Source: It consists of leaves of *Murraya koenigii* belonging to family Rutaceae^[13].

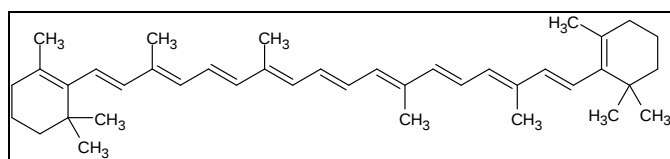


Fig 9: *Murraya koenigii* (Curry leaves)

Phytoconstitute: The main phytoconstituent in curry leaves that is believed to contribute to these benefits is beta-carotene^[13].

Chemical constituent^[13]

- Essential oil
- protein
- minerals
- vitamin



Beta-carotene

Mode of action^[44]

- Curry leaves (*Murraya koenigii*) are widely utilised in cuisine and traditional medicine due to their numerous health advantages. They are frequently linked to improved hair health, including the capacity for melanin synthesis. Curry leaves may promote hair growth and melanin synthesis through the following mechanisms:

Rich Nutrient Profile

- Curry leaves contain vitamins A, B, C, and E, along with minerals such as calcium, iron, and magnesium. These minerals are needed for healthy hair development and melanin production.
- **Vitamin A:** promotes healthy scalp and hair growth by boosting sebum production, keeping the scalp moisturised.
- **Vitamin B:** Complex promotes hair development and

health by regulating cell metabolism and preventing hair loss. B vitamins, including B6 and B12, are very good to hair health.

- **Vitamin C:** An antioxidant that protects hair follicles from oxidative stress and promotes collagen formation, essential for healthy hair.

Use: It is used for strengthening the hair fibers, encourage fast hair growth and prevent hair loss amino acids present in the curry leaves help retain hair strength and hair shine^[13].

Ginseng

Biological source: It consists of dried root of various species of *panax*, like *P. ginseng* (Korean ginseng), *P. japonica* (Japanese ginseng), *P. notoginseng* (Chinese ginseng) and *P. quinquefolium* (American ginseng) belonging to family Araliaceae^[11].

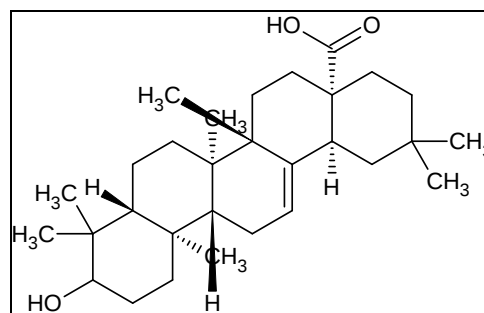


Fig 10: *Panax ginseng* (Ginseng)

Phytoconstituents: The main active compound in ginseng is ginsenosides (Or panaxosides). Ginsenosides contain aglycone dammarol while panaxosides have oleanolic acid as aglycone^[11].

Chemical constituents^[11]

- Ginsenosides
- Panaxosides
- Chikusetsusaponin



Oleanolic acid

Mode of action^[45]

The phytoconstituents in ginseng work synergistically to:

- **Stimulate Hair Follicles:** Ginsenosides stimulate the development of hair follicles and extend the anagen (growth) phase of the cycle.
- **Improve Scalp Health:** Anti-inflammatory and antibacterial qualities provide a healthy scalp environment.
- **Enhance Blood Circulation:** Improved circulation ensures that the hair follicles get enough nourishment and oxygen.
- **Provide Antioxidant Protection:** Ginseng contains

antioxidants that protect hair follicles from free radical damage and environmental stresses.

Use

Ginseng extracts are often included in hair care products like shampoos, conditioners, and hair masks. These products can be applied directly to the scalp and hair to provide localized benefits [46].

Hibiscus

Biological Source: It consists of whole plant of *Hibiscus rosa-sinensis*, belonging to family Malvaceae [47].



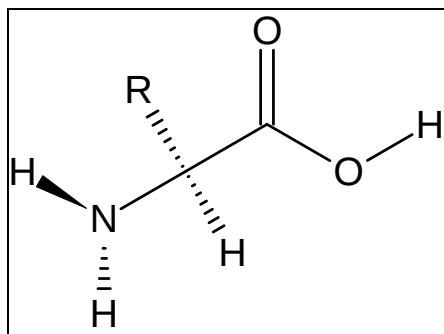
Fig 11: *Hibiscus rosa-sinensis* (Hibiscus)

Phytoconstituents

Tannins, steroids, alkaloids, amino acids [13].

Chemical constituents [48]

- Flavonoids
- Saponins
- Phenol



Amino acid

Mode of action [49]

Hibiscus includes amino acids, which can aid to improve blood circulation in the scalp and promote hair development. It can also assist to strengthen the hair shaft and reduce breakage. Hibiscus can assist to condition your hair, making it softer and more manageable.

Use

Hibiscus extract have been used for again in Ayurveda to cure many ailments. They are used to cure ailments such as hair loss and hair graying [13].

Licorice root

Biological source

It consists of roots of *Glycyrrhiza* (*Glycyrrhiza uralensis* Fisch, *Glycyrrhiza glabra* L, or *Glycyrrhiza inflata* Bat, *Leguminosae*) belonging to family Fabaceae [50].



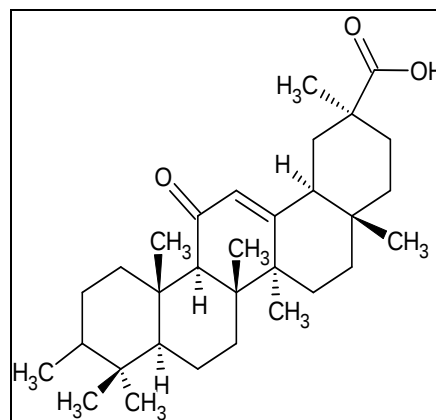
Fig 12: Glycyrrhizin acid (licorice root)

Phytoconstituents: The phytoconstituents in licorice that are thought to contribute to hair growth include:

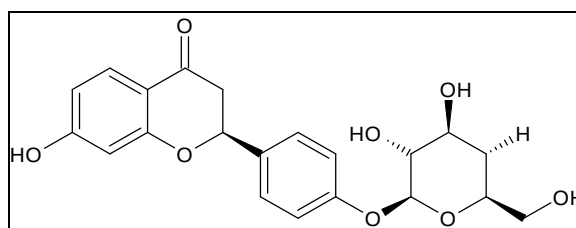
Glycyrrhizin, Liquiritin, Glabridin, Polysaccharides [51].

Chemical constituents [52]

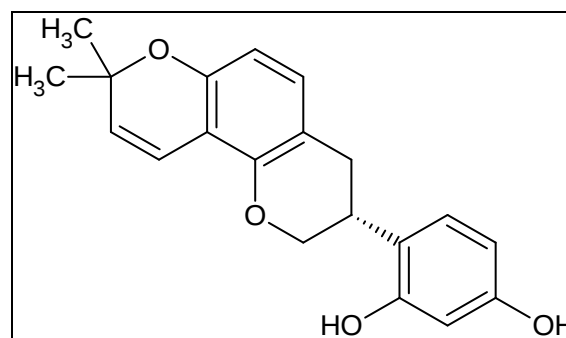
- Flavonoids
- Isoflavonoids
- Coumarins
- Sterols



Glycyrrhizin



Liquiritin



Glabridin

Mode of action

Liquorice root is thought to promote hair growth through a variety of processes, but more research is needed to completely understand its efficacy and method of action. Here

are some important mechanisms:

- **Anti-Inflammatory effects:** Glycyrrhizin and other chemicals in liquorice root are anti-inflammatory. Reducing inflammation on the scalp can help produce a healthier environment for hair follicles, promoting hair development^[53].
- **Antioxidant activity:** Liquorice root includes flavonoids and other antioxidants that help to neutralise free radicals. This reduction in oxidative stress can protect hair follicles and improve their health^[54].
- **Hormonal modulation:** Licochalcone A, a chemical found in liquorice root, has been researched for its ability to block the enzyme 5-alpha reductase. This enzyme transforms testosterone into dihydrotestosterone (DHT), which is associated with hair loss in disorders such as androgenetic alopecia. Liquorice root, which inhibits this enzyme, may help lower DHT levels and hair loss^[55].
- **Moisturizing properties:** The polysaccharides in liquorice root can help keep the scalp hydrated. A well-moisturized scalp is less likely to experience dryness and irritation, which can benefit overall hair health and development^[56].
- **Improvement in scalp health:** Liquorice root may also contain antibacterial qualities, which aid in keeping the scalp clean and clear of infections or fungal problems that might inhibit hair growth^[57].

Use: It is used for nourishing the hairs^[58].

Triphala

Biological source

It consists of fruits of *Embilica officinalis* (Indian gooseberry), *Terminalia bellerica* (Belleric myrobalan), and *Terminalia chebula* (Chebulic myrobalan) belonging to Family Combretaceae^[59].



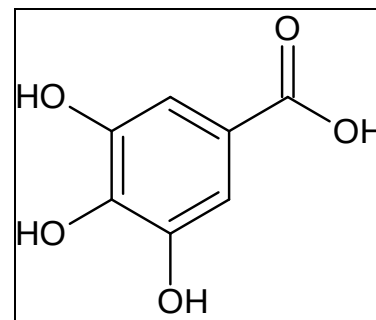
Fig 13: Triphala

Phytoconstituents

The major phytoconstituent of *T. bellerica*, *T. chebula* and *P. emblica* fruits is gallic acid^[60].

Chemical constituents^[61]

- β -sitosterol
- Ethyl gallate
- Galloyl glucose
- Chebulaginic acid



Gallic acid

Mode of action^[62]

Consuming triphala with warm water as a tea may improve blood circulation, stimulating your hair follicles and treating scalp disorders to promote healthy hair development. Vibhitaka, one of the three plants used in triphala churna, has both antifungal and antibacterial effects.

Use: It is used to stimulate the hair follicles and roots to encourage hair growth^[63].

Conclusions

Melanin plays a crucial role in hair pigmentation, protection, and overall health. Its synthesis is a complex biochemical process that determines hair color through the balance of eumelanin and pheomelanin, and its presence also provides essential UV protection. Age-related reduction in melanin leads to greying of hair, highlighting its significance in maintaining youthful hair appearance. From the above study various natural herbs, including almond, amla, ashwagandha, bhringaraj, and many others, show promising potential in improving melanin synthesis and promoting hair growth. These herbs, rich in antioxidants, vitamins, and bioactive compounds, not only strengthen hair follicles but also help delay hair greying, reduce hair loss, and enhance overall scalp health. Their traditional and modern uses in promoting hair wellness emphasize the importance of a holistic approach to hair care through natural remedies.

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