

Herbal Hair Dye: A Comprehensive Review of Botanical Alternatives in Hair Coloring

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ABSTRACT

Ancient cultures around the world employed hair colour as one of their earliest recipes. These days, the popular hair colors are synthetic and contain peroxide and ammonia, which harm the structure of hair. Hair plays a major part in one's appearance, and people are becoming more aware of this. Herbal medicines, which are renowned for their lack of side effects, are preferred for preserving healthy hair. About 70% of those over the age of 50 have problems such as hair graying and baldness. In certain situations, these aging indicators could show up early. Around the age of forty, the graying process usually starts at the temples and moves up to the beard, mustache, and finally the chest. A significant issue stems from the growing risks to the surroundings and human health associated with staining products and their widespread use worldwide. For this reason, working on the volition of synthetic and semi-synthetic stains has been feasible. The synthetic oxidative hair stains that are accessible in the request include an ammonia and peroxide combination that damages hair and has negative effects. Additionally, some users of synthetic stains run the risk of developing non-Hodgkin's lump, bladder cancer, and rapid cancer. Hair stains are safe to use and are said to solve these issues from workshops. Henna, butterfly pea, Reetha, walnuts, coffee, clove, bhringraj, and other uncountable natural herbal remedies are among them. Herbal hair color is employed for a variety of colored conditions, such as head lice, premature graying of the hair, and dandruff. Natural hair stains address the issue of pollutant and hair cuticle degradation while remaining safe for application.

KEYWORDS: Hair Coloring, dye, herbal cosmetics, formulations

I. INTRODUCTION

The human urge to seem beautiful is a weakness that has existed since the beginning of time and affects all ages of people. Nowadays, everyone is quite conscious of their appearance. Humans take care of every area of their bodies to seem beautiful, and there are many products on the

market that can help achieve this goal. Products can be synthetic, natural, or semi-synthetic that are sold in the market. Human hair plays a significant part in appearance. Baldness and hair graying are problems for those with 60 to 70%. People begin to gray when they have a vitamin B12 deficiency, thyroid condition, or impacted heredity. Adults are mostly at risk for early depigmentation from conditions like illness, UV radiation, stress, alcohol use, some medications, shock, and more [1]. The synthetic hair dyes that are utilized to modify the color of hair have a high frequency and have the potential to damage hair structure because of how they work. Therefore, safe herbal medications are used for healthy hair. Herbal medicines, which comprise either raw or processed substances from one or more plants, are plant-derived materials or products collected from stems, seeds, leaves, flowers, and roots and used for human purposes. Herbal shampoos, tablets, hair dyes, toothpastes, and other cosmetic formulas contain a variety of herbs, including shikakai, henna, bhringraj, and others. Herbal medicines were utilized in the past to color carpets, rugs, and garments by using the stems, roots, bark, leaves, berries, and flowers of different plants that produce dyes. Due to their inherent goodness and absence of adverse consequences, the demand for natural treatments based on herbs is growing quickly [2]. Well-known ayurvedic herbal remedies including Bhringraj, Henna, Reetha, and methi seed have traditionally been employed as hair colorants and to promote hair growth. Natural dyes are less harmful to the environment, less inflammatory, and less poisonous. Herbal dyes' structural components include catechins, flavonoids, ascorbic acid, and other substances that naturally exhibit antioxidant properties. Herbal hair dyes are effective in treating several conditions, including head lice, dandruff, and premature graying of the hair. Natural hair dyes are safe to use and tackle the issue of scalp and hair cuticle deterioration by using more natural substances to color hair without the usage of chemicals. Pigments that are available in natural hair colors include caramel, yellow carotene,

yellow lutein, red anthocyanins, curcumin, caramel acid, and riboflavin. There are a lot of formulations on the Indian market. The formulations majorly comprise more than five herbal medications, whereas only a small number contain five or fewer [3].

1.1. HAIR

In humans, hair particularly the brows, eyelashes, and scalp hair—serves vital defensive purposes. These characteristics are frequently valued and seen as unique in females. As scalp hair protects the head and neck from the sun, cold, and physical harm, eyebrows, lashes, and other foreign objects help keep the eyes safe. Hair serves as a natural barrier against a variety of environmental variables and mechanical assaults to the skin, which further aids in-home therapy [4]. Additionally, hair contributes to our capability to perceive touch cues on the skin. It also plays a significant role in social and sexual communication. Hair abnormalities, such as overgrowth or loss, can significantly affect a person's quality of life psychologically. For instance, individuals experiencing androgenetic alopecia have been reported to have a higher prevalence of personality disorders compared to the general population. This highlights the emotional and social aspects associated with hair-related conditions [5].

1.1.1. History of hair colouring

Since Ramesses II, the pharaoh of Egypt's nineteenth dynasty, had henna added to his hair after his death, the skill of hair coloring has been recognized. Hair was bleached in ancient Greece with a potassium solution rinse and then massaged with an ointment made of pollen and flower petals.

Hair coloring in various hues, including black, green, red, and gold, was a common technique in the past. In a lab, the first artificial hair color was created in 1856. German chemist Hofmann first described para-phenylenediamines in 1863, and in the late 1800s, the compound was developed for use in hair dye [6].

1.1.2. Anatomy and Physiology of the Hair Structure of Hair

A Dead, keratinized cells are bonded together to form hair. The shaft is the segment of hair that is perceptible above the skin. The cross-section of straight hair is round, that of wavy hair is oval, and that of woolly hair is elliptical or kidney shaped. The portion of hair that extends into the dermis and occasionally the subcutaneous layer is called the root. There are three concentrically organized layers in both the shaft and the root. Its three basic components make up a complex structure as shown in figure 1:

- **Bulb:** An enlargement in the dermis at the base. Bulb helps in growing of hairs, which is also its deepest end. It is linked to the dermal papillae, which are vascularized and highly innervated and enable the delivery of nutrients required for hair growth [7].
- **Root:** It exists beneath the epidermis. The portion of hair that is situated between the bulb and the exterior of the epidermis, where the hair assumes the shape of a stem, is where the root is securely embedded in the hair follicle. The medulla, cortex, and cuticle on the outside are the three concentric layers that make up the root and stem.
- **Shaft:** The evident part of hair protruding above the skin [8].



Figure 1: Anatomy of hair

➤ **Medulla:** The midline region of the hair shaft is called the medulla. Usually seen in thick

hair. Composed of air and pigment granules arranged in two or three rows of cells.

- **Cortex:** The cortex, which comprises the preponderance of the hair shaft, is located around the medulla. Consisting of lengthy cells. Contains air in white hair and pigment particles in dark hair. It is composed of densely packed, spindle-shaped cortical cells, an amorphous template of high sulfur proteins, and keratin filaments that are parallel to the longitudinal axis of the hair shaft [9].
- **Cuticle:** It is the hair's outermost layer. Consists of one layer made up of flat, thin cells. Because of their high keratinization, these cells give the hair a protective coating. Cuticle is a layer of dead cells that overlap and are incredibly resistant. Endocuticle and exocuticle make up this structure. Smooth cuticles allow light to reflect off of them and reduce friction amid the hair shafts. It does in fact; give hair its sheen and texture. The major substance in hair is keratin. Tyrosine, glycine, and cysteine make up the majority of this fibrous, resistant protein's amino acidic chains, which are arranged in α helix. Typically, it exists as basic, neutral, and acidic keratin [10].

1.1.3. Physiology of the Hair

A number of variables within the hair follicle affect the growth and development of hair molecules. Hormones, cytokines, and outside variables control the dynamic, cyclical process. In addition to the hair's location, other factors that affect growth cycle duration include age, nutritional status, developmental stage, and changes in the environment, such as the length of the day. In essence, a multifaceted interplay of biological, hormonal, and environmental factors affects hair health and growth. Hair grows in recurring cycles, with intervals of relative rest and hair follicle regression interspersed with periods of active growth and hair creation [11].

- **Anagen Phase (Growth Phase):**

This is an active expansion phase where the hair follicle enlarges, taking on a distinctive onionshape. It is alienated into six stages (I-V and VI).

In stages I-V (proanagen), hair progenitor cells proliferate, envelop the mounting dermal papilla, grow into the skin, and start turning into the hair shaft.

During anagen VI (metanagen), the full restitution of the locks fiber-producing entity occurs. This is marketed by the arrangement of the epithelial bulb concerning the dermal papilla, deep

in the skin, and the new hair shaft emerges from the skin surface.

This phase can last for numerous years in hair follicles [12].

- **Catagen Phase (Transitional Phase):**

This is a transitional phase amid active growth and regression. It's a relatively short phase where the shrinkage and detachment of hair follicle occurs from dermal papilla.

- **Telogen Phase (Resting Phase):**

This is a resting phase where the hair follicle is in a state of relative quiescence.

During this phase, no active hair growth occurs, and the hair is anchored in the follicle. Eventually, the cycle restarts with the return to the anagen phase. In essence, hair growth involves a dynamic process with periods of growth, transition, and rest, with each hair follicle going through these phases repeatedly over time [13].

II. HAIR DYE

Graying hair can be caused by a variety of circumstances, such as underlying medical disorders, stress, a diet deficient in essential nutrients, and hereditary. 50% of people worldwide are expected to have gray hair before the age of fifty; hence genetics is typically the main factor causing early graying. Individuals frequently conceal or alter the color of their gray hair with chemical-based hair dyes. Alternatively, these hues may cause skin disorders and other associated issues. Natural herbal dyes are growing in popularity as many perceive them to be safer alternatives. People are paying greater concentration to how they look, and hair plays a big role in appearance and requires being maintained [14].

Natural plant dyes have been utilized to dye carpets and rugs for a very long time. These days, owing to their natural benefits and low risk of side effects, consumers prefer these herbal hair dyes over ones made of chemicals. Skin issues might result from hair dyes with chemicals in them. Herbal-based natural treatments are growing more and more popular because of their goodness and safety. Herbal-based natural treatments are growing more and more popular because of their goodness and safety. Herbal remedies are used in Ayurvedic medicine to promote hair growth and color [15].

Hair is essential to people's increasing understanding of their own beauty. Around 70% of adults over 50 grow graying or balding hair as they

age. While there is some genetic influence on the period at which graying starts, a range of factors, such as illness, certain drugs, and stress, can cause humans to lose their pigmentation too soon. In India, hair and hands are traditionally colored for celebrations using natural colors like henna. These plant-based medications have few side effects, are widely available, reasonably priced, safe, and

effective. In the contemporary eco-conservation period, using natural colors also aligns with environmental concerns. Hair affects how someone displays their personality and sense of self in a way that goes beyond just being a physical trait. There are three main types of hair dyes; temporary, semi-permanent, and permanent as shown in figure 2 [16].

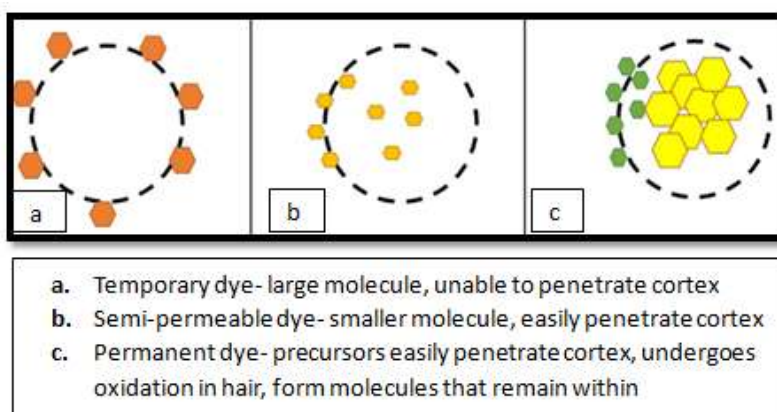


Figure 2: Types of hair dye

1.2. Temporary Hair Dyes: These colors are soluble in water and have a high molecular weight. Instead of penetrating the hair shaft, they stay on the exterior of the hair. Are sometimes created from organic ingredients, like henna, and are simple to take off with regular cleaning. This sort of dye cannot be used to whiten individual hair strands; instead, it is intended just to add new highlights to the hair, not to alter its color entirely. White, blond, or bleached hair might benefit from fresh color application because it will show off the recently applied color because of the background color of the hair strand. The temporary coloring can be used to cover a small section of white hair, add colorful reflections, and get rid of the white hair's yellowish affects. Because of its capacity to deposit on hair strands, hair containing equal to 15% white hair can be colored. These dyes with acidic qualities generally have high molar weights based on their structures. Their selection was based on anionic qualities, which provide maximum water solubility and little hair penetration, guaranteeing eradication in the initial washing. There are two ways to apply them: continually (progressively) or all at once with a single wash at the conclusion of the application procedure to eliminate the excess unabsorbed dye on the hair. They are

available in shampoo, gel, emulsion, and solution (liquid) form [17].

1.3. Semi-Permanent Hair Dyes: often synthetic and composed of lower molecular weight coal tar components. Can enter the hair cortex and exit again. Endure more rubbing than temporary hair color. The process of coloring hair does not include an oxidation reaction; it is a simple application that takes 10 to 40 minutes, after which the hair is rinsed. These cosmetic forms need to have the ideal viscosity in order to stay in place during application. Because low molar mass dyes have a high pH value that causes the cuticles to expand, they only slightly pierce the cortex. Semi-permanent hair products stimulate significant hair color retention (resistance up to 20 washes) because they consist of a mix of semi-permanent molecules with oxidation dye precursors, useful with hydrogen peroxide (H₂O₂).

1.4. Permanent Hair Dyes: mostly used to provide long-lasting color effects. Bleaching the hair is the first step in the process. Couplers, oxidants (such as hydrogen peroxide and ammonium/sodium per sulfates), and primary intermediates are the three main components required for the oxidation process. To achieve the appropriate final hair color, reactions between couplers and primary intermediates

(such p-phenylenediamines) occur after bleaching. Simply defined, a dye is any colored material that has a strong affinity for fibers; they are particularly well-liked due to their capability to darken hair and stay a long time.

Before dying, the hair needs to be bleached with specific chemical components to get the desired color. Approximately 80% of hair colors on the market fall into this category, which can be any color and can cover up to 100% of

white hair strands. In addition, both light and dark natural hair hues are possible thanks to the interaction of ammonia hydroxide and oxidizing agents. Since semi permanent hair dye contains monoethanolamine, which has a lower color lightening power than permanent hair dye, the alkalizing agent used in the former is very different from that used in the latter. Precursors and oxidizing agents interact intricately to produce color through their combination. There are two categories of precursors: couplers also called as reaction modifiers, and oxidation basis [18].

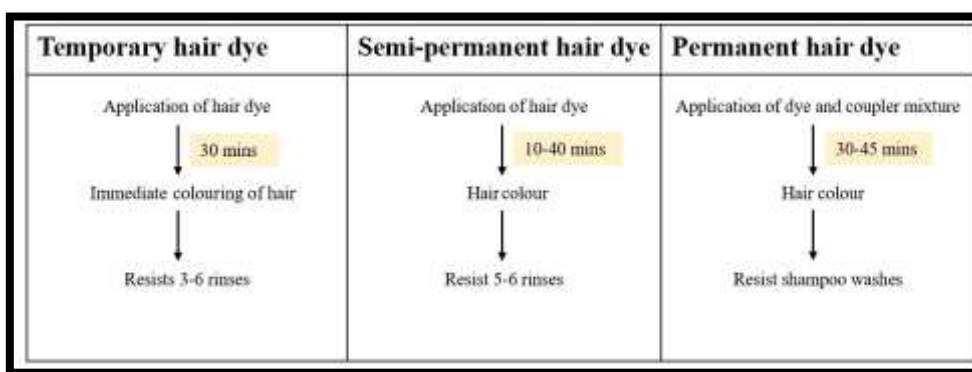


Figure 3: Various steps involved in hair dyeing

Melanin

Human skin, eyes, and hair are colored by a chemical called melanin. It is made up of two primary types: pheomelanin and eumelanin, which together define the color of your natural hair. A collection of linked molecules called melanin is found in many creatures, including humans, and serves a variety of biological purposes. It is essential for regulating the pigmentation of the skin, hair, and eyes in our body. Three varieties of melanin exist:

Eumelanin: in charge of producing hues with dark pigmentation, such as dark brown and black [19].

Pheomelanin: Lighter pigmentation, such as pink or red lips and red hair, is caused by pheomelanin.

Neuromelanin: Although it is also present, neuromelanin has little effect on the color of the skin, hair, or eyes.

So, melanin is the substance that provides color to our skin, eyes, and hair, and the ratio of eumelanin to pheomelanin determines the normal color of our hair. Eumelanin gives darker shades, while pheomelanin gives lighter tones, the color of your hair is controlled by melanin, and the specific shade resist on the type and quantity of melanin present [20].

For instance:

Black hair contains a large amount of eumelanin. Brown hair has an average amount of eumelanin. Blond hair indicates a low amount of eumelanin. Red or pinkish blond hair outcome from a considerable quantity of pheomelanin with a bit of eumelanin.

Additionally, melanin serves as a barrier against UV radiation, giving darker hair tones increased protection. For both men and women, hair dye is an important cosmetic. Permanent or synthetic hair dyes usually contain color and developer, which can be strong irritants and be connected to allergies and health problems. The possibility of breast cancer may rise with continued use of permanent or semi-permanent hair color. Long-term hair dye use can frequently result in skin toxicity and localized discomfort [21].

III. HERBAL HAIR DYE

Henna, chamomile, indigo, and other plant ingredients have been used by people to naturally color their silver hair and give it a dark shade during earliest times. However, people frequently end up with reddish-copper tones instead of black. The use of harsh drugs, environmental conditions, hereditary influences, and other reasons can all be blamed for the decline in the range of hair colors.

Long-lasting synthetic hair colors preserve natural luster and provide a variety of possibilities, but they have the serious disadvantage of potentially triggering allergic reactions in certain people. Even hair colors labeled as natural sometimes contain artificial ingredients like phenylenediamine, which can cause skin irritation and discolor clothing while being applied [22].

With the goal of developing a safe hair colorant that prevents skin discoloration and allergic responses, this study recognizes the need for a product made entirely of plant-based chemicals. The goal of the research is to create a naturally dark color by combining several plant elements. Natural hair dyes, such as brown hair dyes derived from henna, provide an answer by shielding the scalp from irritation, cuticle damage, and other problems. Use of these natural substitutes is risk-free and does not result in skin discoloration, itchiness, or allergic reactions. The ancient art of dyeing, which dates back to the Bronze Age, has developed over time, with rudimentary procedures giving way to more sophisticated ones that use natural colors. Up until the middle of the nineteenth century, textile products were primarily colored using natural dyes [23].

Following that, there was a sharp rise in demand for synthetic supplies due to their low expenditure, ease of production, and availability in anamplerevariety of colors that remained colorfast. As a result, by the early twentieth century, the practice of natural dyes had significantly decreased. It's crucial to remember that "natural" does not always equate to safe. Safety records sheets are accessible for each synthetic dye, and tests on the dyes' toxicological characteristics have been conducted by scientists. Nevertheless, comparable thorough investigations about the safety of natural dyes are not as easily accessible. Although most natural dyes are benign, some might be harmful. For example, depending on the type of mordant used, logwood, a natural dye can yield a variety of colors, such as violets, blue-greys, and the best natural black [24].

Natural herbal hair dyes are becoming more and more popular these days as a substitute to chemical-based hair colors, which can result in skin conditions and other related illnesses [25]. Genetics has a chief function in when graying occurs, but there are a numeral of other conditions that can cause premature depigmentation in adults, including illness, some medications, stress, and more. Natural dyes have been used historically for a variety of purposes, such as coloring clothes,

carpets, and rugs. The roots, barks, leaves, stems, berries, and flowers of several plants that produce dyes are the sources of these natural colors. Any material, synthetic or natural, that is used to give anything color or alter its already existing color is called a dye. For instance, "blond hair dye" describes a chemical that is used to dye blonde hair. The preponderance of dyes naturally comes from plant sources, including roots and leaves [26, 27]

The objectives of herbal dye comprise:

- Combining several natural dye extraction techniques into a single document.
- Illustrating the various natural dye kinds' fastness qualities, or how well the color endures over time.
- Outlining distinct extraction techniques appropriate for a range of sources.
- Analyzing a range of factors, including patch tests, phytoconstituents, physico-chemical, organoleptic (sensory), rheological (flow qualities), and testing to determine efficacy and shelf life [28].

Advantages:

- Chemical-free and Natural substances: Utilizes a greater amount of natural substances while avoiding the use of chemicals.
- Natural hair color that successfully covers gray hair without having any negative side effects is available.
- Deep Conditioning and Nourishment: This method deeply feeds and conditions hair strands from the inside out [29].
- Addresses Current Hair Issues: Assists in resolving current hair issues.
- Natural Appearance with actual Human Hair Fibers: The usage of actual human hair fibers produces a natural appearance.
- Flexibility in styling: May be worn in a natural hairstyle.
- Less Vulnerability to Heat Damage: Exhibits a lower susceptibility to heat-related damage.
- Color and perming compatibility: Enables coloring and perming.
- Natural Movement: This hair type behaves and moves naturally [30, 31]

Disadvantages:

- Higher Cost: Generally speaking, it's more costly than synthetic substitutes.
- Needs More Maintenance: Needs more upkeep and attention.
- Styling Required: Styling is necessary to get desired results.

- Sunlight sensitivity fading and Environmental Damage: More vulnerable to environmental influences including fading from sunshine.
- Potentially Heavier Weight: This wig might weigh additional than synthetic wigs, which could make itchy [32].

1.5. Method of hair dye preparation

- Weighing: Determine the weight of the ingredients needed for the batch. Small batches require a less number of ingredients, while large batches require a larger amount.
- Mixing: The components are just being combined after being weighed and checked. All of the ingredients are thoroughly combined.
- Filling: After the completed batch of hair product is transported to the filling section, the amount of hair dye is measured and poured into bottles.
- Packaging: Plastic bottles are taken from the filling area. After the bottles are fully packaged and labelled at the packing line, the product is transported to a warehouse or storage location where it will be distributed [33].

1.6. Hair Colouring Mechanisms

There are two methods for colouring hair with natural plant-based hair dyes: direct dyeing and mordant dyeing. In a nutshell, there are two phases involved in dyeing hair:

- i. Diffusion of dye molecules from the dye bath to the keratinous hair fiber;
 - ii. With or without the help of additional mordanting agents, the carboxyl or hydroxyl groups in the dye molecules and the amino/sulfhydryl groups in hair keratin form chemical bonds. The process of diffusion has three stages [34].
- Transporting dye molecules to the fiber/water interface through a combination of agitation and aqueous diffusion.
 - The second stage involves the adsorption of dyestuffs onto the cuticle layer of hair.
 - The final stage, which is marked by a change in the cell membrane complex (CMC) found in the hair cuticle, is the diffusion of low molecular weight dye molecules into the inner hair structures [35].

The intercellular matrix, or CMC, is a continuous phase that connects the cortical cells and cuticle. According to studies, the primary route by which color chemicals are transported to the hair

cortex is by CMC penetration. Small compounds with lower ionization levels have a higher probability of passing through and across the lipid bilayer of CMC. Furthermore, the state of hair fibres influences how external dye ingredients are absorbed and diffused. For instance, the disulfide bonds in hair keratin can be broken by using hydrogen peroxide in hair dye formulations. This can lead to CMC breakage, reparation to the cuticle and cortex components, and swelling of loose hair fibres and lifted cuticles. These effects enable stronger bonding and deeper penetration of dyestuffs into the hair exterior shaft [36].

As a nonoxidative method of hair colouring, direct dyeing involves the direct formation of a dye-complex amid the dye and the hair fiber. The appeal of dye molecules to the exterior of the hair fiber determines the color potency of directly dyed hair. Low molecular weight dyes the essential sizes for anionic dyes are 1.2–1.3 nm, for cationic dyes, 1.4 nm, and for non-ionic dyes, 0.95 nm generally have an easy time penetrating the cuticle layer of hair fiber. High molecular weight dyes can be adsorbed onto hair fiber by a variety of forces, including hydrogen bonding, Vander Waals, and electrostatic forces, but they cannot pass through the cuticles. Natural dyes made from henna plants and walnut husks are well-known examples of direct dyes [37].

1.7. Technological Innovations for Natural Hair Dyeing

i. Production of Colorants Using Synthetic Biology Methods

The reliance on intricate extraction and purification processes, anextensivearray of botanical sources, protracted growing cycles, and finite harvest seasons constrain traditional techniques of extracting colorants for hair dyes from plants. Synthetic biology methods have made it possible to produce plant colorants by microbial fermentation with new tools in recent years. The potential to alter or introduce colorant-formation genes into microorganisms for increased production of anthocyanins, curcumin, and carotenoids has been demonstrated by metabolic and genetic engineering techniques. Yan et al. reported on the first microbial production of anthocyanins [38]. They created a four-step metabolic pathway in engineered E. coli that had heterologous plant genes, and the cytosol was able to absorb naringenin and mustard alcohol to make anthocyanins 3-O-glucoside. Similarly, curcumin synthase 1 (CURS1) from turmeric, diketide CoA

synthase (DCS), and 4-coumarate-CoA ligase (4CL1) from *Arabidopsis thaliana* were used to generate curcumin heterologously in modified *E. coli*. Furthermore, with the use of metabolic engineering approaches, a more effective β -carotene biosynthesis pathway was created in microorganisms by over expressing genes relevant to the mevalonate pathway. However, the conception of heterogeneous microbial cubicle factories is laborious and time-consuming, despite the significant advancements in the domains of metabolic engineering and synthetic biology. Furthermore, there has been an assortment of concern recently about the possible bio safety issues associated with synthetic biology. Therefore, the industrialization of such technologies to create diverse kinds of natural colorants and use them in cosmetic hair dyes remains difficult [39, 40].

ii. Encapsulation of Colorants for Stabilization and Detoxification

When employing natural colorants in hair coloring cosmetics, stability considerations must be taken into consideration. Over the years, a number of effective encapsulation techniques have been developed to shield delicate phytochemicals or plant extracts from environmental challenges such as heat, UV light, and extreme pH levels. Encapsulation presents a viable approach to safeguard delicate dye molecules in commercial hair dye products by enveloping them in an external shell (wall material), so guaranteeing the stability and dyeability of natural colorants. Numerous encapsulation techniques, such as chemical (emulsion polymerization, suspension polymerization, and interfacial polymerization) and physical (spray-drying, spraycooling, and co-extrusion) methods can be used to create microcapsules containing natural colorants. Thus, stability and compatibility problems in natural

dyeing using plant colorants have been addressed via encapsulation technology [41].

iii. Inorganic Nanocarrier Development for Effective Hair Dyeing









Nanomaterials are excellent carriers of bioactive substances for cosmetic applications because of their small particle size, vast surface area, and nanostructure, as well as their adaptable physicochemical properties. Different inorganic nano-carriers, such as nanoparticles, nanofibers, and nanotubes, have demonstrated their value in stabilizing plant dyes used in hair coloring and improving the dyeing result in recent years. For instance, tiny carbon nanotubes with a higher surface to volume ratio can readily interact with hair fibers by absorption onto cuticles, improving affinity and producing long-lasting coloring effects. Due to their local surface plasma resonance characteristics, gallic acid reduced/functionalized silver nanoparticles and colored silica nanoparticles have also been created as innovative dyes for bleached human hair. Additionally, it was demonstrated that oxidizing dopamine to produce polydopamine that resembles eumelanin and depositing these nanoparticles on the surface of hair is a novel biomimetic approach to creating pigments that mimic melanin for hair coloring [42].






iv. **Enzymatic Processes:** Enzymes can be used to extract color from natural sources more efficiently. Enzymatic processes are environmentally friendly and can produce vibrant hues without the need for harsh chemicals or high temperatures.

v. **Micro-Emulsion Technology:** This technology involves breaking down natural dye molecules into tiny droplets that can penetrate the hair shaft more effectively, resulting in better color retention and coverage. It also helps to minimize potential damage to the hair cuticle [43].

Table 1: List of various herbal crude drugs used to prepare hair dye

SR NO.	Drug with common name and description	Herbal crude drugs	Uses
1-	Indigo powder True indigo or nil, obtained from leaves of <i>Indigofera tinctoria</i>		Coloring agent, promote hair growth ⁴⁴

2-	Fenugreek Methiconist of dried seeds of plant <i>Trigonella foenum</i> .		Hair growth promoter ⁴⁵
3-	Orange peel It consists of fresh fruits of plant <i>Citrus aurantarium</i> . Family: Rutaceae		Hair growth promoter ⁴⁵
4-	Peppermint <i>Mentha piperata</i> is a strongly scented perennial herb Family-Labiatae		Hair growth promoter, improve scalp ⁴⁶
5-	Marigold (Genda) It consists of flowers and petals of <i>Tagetes erecta</i> Family - Asteraceae		Improve hair health, boost hair growth ⁴⁶
6-	Custard apple seeds Sharifa, sitaphal, sugar apple It consists of dried seeds of <i>Annona squamosa</i> Family- Annonaceae		Anti-lice agent, prevent premature graying ⁴⁷
7-	Banana peel It consist of fruit of <i>Musa acuminata</i> Family- Musaceae		Provide shine to hair and strengthen hair and improve hair health ⁴⁸
8-	Coffee It consists of dried ripe seeds of <i>Coffea arabica</i> Family- Rubiaceae		Reduce hair loss and encourage hair growth, darken hair ⁴⁹
9-	Beetroot It consist of <i>Beta vulgaris</i> Family- chenopodiaceae		Reduces hair breakage, nourishes hair follicles, and helps to delay premature graying. ⁴⁹

10-	Cinnamon It consists of dried inner bark of shoot of tree Cinnamomum zeylanicum Family- Lauraceae		Possess anti fungal properties, stimulate circulation, encourage hair growth and reduce hair loss ⁵⁰
11-	Black sesame Kaale til It consists of seeds of Sesamum indicum Family- Pedaliaceae		Strengthen hair follicles, improve hair health , promote hair growth , stimulate melanocyte activity ⁵⁰
12-	Black seed It consists of seeds of Nigella sativa Family- Ranunculaceae		Minimizes dandruff, moisturizes hair, soothes scalp dryness, and prevents graying. ⁵¹
13-	Turmeric It consists of dried rhizomes of Curcuma longa Family- Zingiberaceae		Thickens hair, stimulate hair growth, anti bacterial in nature ,promote hair growth ⁵²
14-	Rose It consists of flowers and petals of Rosa hybrida Family- Rosaceae		Conditions hair, nourishes the scalp, reduces dandruff , promotes hair growth ⁵³

IV. COMPARISON BETWEEN MARKETED SYNTHETIC FORMULATIONS V/S HERBAL FORMULATIONS:-

Most of the people in rural and urban areas depend upon herbs for traditional cosmetics. The need of herbal based natural ingredients is increasing nowadays due to their natural goodness and less number of side effects. Amla, indigo, methi, henna, tea, curry leaves, lemon juice, beetroot juice, Bhringraj, honey, shikakai are well-known herbal drugs traditionally used as hair colorant and for hair

growth as equated to the chemical based hair dyes, which grounds skin and other skin associated diseases due to various chemical ingredients used in them [54].

Natural dyes are eco-friendly for exemplar, turmeric; the brightest in nature shows yellow dyes is a prevailing antiseptic and also promotes hair growth, whereas indigo gives a cooling sensation. The advantages of employing natural colorants are plentiful. They are safe for the body, ethereal, and in harmony with nature, derived from natural sources. Additionally, their preparation carries minimal risk of chemical reactions. The shades fashioned by natural dyes are generally soft,





gleaming and comforting to the human eye. Generally they do not cause wellbeing hazards; on the contrary, they sometimes act as health-care substances. Moreover, the exploit of natural dyes offers no dumpinginconvenience. However, they have their own precincts like accessibility, colour yield, stability, and complication of dyingpractice and reproduction of shades. Furthermore, they cannot utterlyreinstate synthetic dyes, but they have their individualconsign in the market [55].

The invention of the first synthetic dyes by William Henry Perkin in 1856 changed the situation dramatically and later, the synthetic dyes inward faster adequacy due to a ample range of applications in diverse fields like food, cosmetic, photodynamic therapy, non-linear optical activity and more importantly in textile industries due to ease in dyeing, and overall cost factor [56]. But, in the last few decades, the use is decreasing gradually due to an increase in environmental awareness and harmful effects of synthetic dyes.

They can be either toxic or non-biodegradable nature in nature. In count to above, some serious physical hazards like allergic and, carcinogenicity are allied with the synthetic dyes [57].

Synthetic hair dyes accessible in the market, generally consists of amalgamation of peroxide and ammonia which alters the structure of hair and damages it and also causes allergic reactions. Paraphenylenediamine (PPD), a key ingredient of many synthetic hair dyes is known to cause allergic skin rashes in many people. It also causes dermatitis around lips, reddening and swelling of scalp and face etc. It has been originate in the local market assessment that largely of the marketed herbal formulations in India, stillallege to be natural, safe and effectualmight actually contain the harmful synthetic agent, paraphenylenediamine (PPD), at 20-25% concentrations which is the foremostconstituent of commercial synthetic dyes [58].

Some of them are illustrated below: [59]

Sr no.	Synthetic hair dyes	Marketed hair dye	Chemical ingredients
1-	Godrej expert rich crème		p-phenylenediamine
2-	L’Oreal Paris Excellence Creme Hair color		p-phenylenediamine
3-	Garnier `hair color		Resorcinol,p-phenylenediamine
4-	L’Oreal Paris casting crème gloss Hair color		Hydrogen peroxide

5-	Schwarzkopf simply color		Hydrogen peroxide
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V. PROBLEMS CONCERNED WITH CHEMICAL BASED HAIR DYE

Nearly all synthetic hair dyes include para-phenylenediamine (PPD), parabens, hydrogen peroxide, and sorbonate. They are essential to the advancement of hair colorants. PPD is used on dark hair tones; however it shouldn't be used frequently to hair for an extended length of time. PPD is a hazardous component of hair dye that can lead to deadly side effects such rhabdomyolysis, renal failure, and respiratory failure. In addition to ammonia, hair dyes also contain hazardous compounds like paraben and hydrogen peroxide that are poisonous to the human body. In order to allow the color to penetrate the hair shaft, the cuticle is opened using hair dye that contains ammonia. Despite its beneficial advantages, it has a number of negative side effects, including lung irritation, cortex damage, frizzy and brittle hair, etc. In addition to PPD and ammonia, other harmful substances that might affect a person's health include paraben, hydrogen peroxide, and resorcinol. These substances can cause hormonal imbalances, scalp irritation, dry hair, flakes, and even hair loss. These substances can lead to chemical burns, dandruff, eye irritation, hair breakage, and occasionally even cancer [60]

Side effects of using hair dyes

Excessive exposure Peroxide and ammonia are ingredients in permanent hair coloring. Because peroxide removes the natural color from hair, frequent exposure to these chemicals can make hair appear dull, brittle, and possibly even cause hair loss. Reactions to allergens Paraphenyldiamine, an allergy, is found in dyes. Dermatitis sufferers may experience a strong reaction as a result. Hair colours are not recommended for people with psoriasis or eczema. In addition to this, it may also result in swelling, redness, itching, and skin irritation. Impact on

Conception Hair colouring during pregnancy has the potential to induce cancer, which can be catastrophic for the foetus. Inhalation Persulfates, which are included in hair colours, can exacerbate asthma. Constant exposure to the toxins might result in lung irritation, coughing, and lung inflammation and even asthma attacks [61, 62].

VI. CONCLUSION

Numerous natural and herbal compounds can be used to encourage hair development and color hair. Because of the negative effects of synthetic dyes, people these days are more accepting of the natural components that form the basis of natural herbal hair colors. Every synthetic dye typically contains harmful substances including paraphenylenediamine (PPD), peroxides, parabens, and others that can damage the body and produce a number of issues that could even be fatal. Compared to hair dyes based on synthetic chemicals, herbal hair dyes color hair much more subtly.

People now prefer herbal hair dyes made of natural components because of their minimal adverse effects. The market for herbal products will overtake synthetic dyes in the next decades. Hair dye with a herbal base has been made. It provides a useful natural substitute. An herbal hair pack gives the hair a very soft color. The non-toxic nature of cosmetics made from herbs is a benefit. It relieves the scalp of extra oil, which aids in the treatment of dandruff. The hair packs with herbal composition, which are great for hair care, contain the goodness of plant powder. These days, people welcome natural cures with open arms because they are less likely to cause adverse effects and are safer than goods made of chemicals. We discovered the herbal hair pack's beneficial qualities in our study, but more research is required to fully understand its potential advantages.

Presently available paste-form natural hair colorants have a number of drawbacks, such as a long soaking period, a messy application, and difficulty rinsing off. This study presents a stable, ready-to-use gel-based formulation of plant powders. Additionally, this produced formulation exhibits good risibility and colouring capabilities. Additionally, it provides advantages including preventing grey hair and promoting hair growth while being safe and ecofriendly.

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