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Research Article

Beetroot in Natural Skincare and Haircare: An In-Depth Exploration of DIY Formulations and Therapeutic Potential

Rahul Chaudhari*[1], Shweta Suryawanshi[2], Sneha Chitkalwar[3], Janhavi Patil[4], Ujwala Gawali[5], Sanket Biradar[6], Sarthak Sanap[7], Payal Jengthe[8], Pooja Hole[9], Harshada Hole[10]

[1,3,4,5,6,7,8,9,10]*Matoshri College of Pharmacy Eklahare.*
[2]*K.V.N. Naik College of Pharmacy Canada Corner Nashik.*

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ABSTRACT

The global shift toward natural and plant-based remedies in personal care has significantly influenced dermatology and trichology, driving the renewed interest in botanicals like beetroot (Beta vulgaris). Celebrated for its vibrant pigmentation and dense nutrient composition, beetroot has emerged as a multifunctional ingredient with considerable potential in skin and hair care. This paper explores the phytochemical constituents of beetroot—including betalains, polyphenols, flavonoids, vitamins, and essential minerals—and their biological activities such as antioxidant, anti-inflammatory, antimicrobial, moisturizing, and tissue-regenerating effects. These properties position beetroot as a natural alternative to synthetic agents in the formulation of cosmetic and therapeutic products. The research further investigates its topical applications for improving skin tone, enhancing hair growth, preventing dandruff, and combating signs of aging and environmental damage. Special attention is given to DIY (Do-It-Yourself) formulations that leverage beetroot's efficacy for home-based skincare and haircare routines, with particular emphasis on seasonal adaptations, especially for winter, when skin and hair are prone to dehydration and damage. Methods of extraction, formulation techniques, stability considerations, and delivery systems are analyzed alongside a discussion of safety profiles, contraindications, and dermal tolerability. Comparative analysis with conventional chemical-based products is conducted to assess relative efficacy and consumer acceptance. This study adopts a multidisciplinary approach encompassing phytotherapy, cosmetic science, dermatopharmacology, ethnobotany, and consumer behavior to provide a holistic evaluation of beetroot's role in modern personal care practices. Supported by extensive peer-reviewed literature, clinical studies, and ethnomedicinal insights, the findings contribute to the growing

***Corresponding Author:** Rahul Chaudhari
Address: *Matoshri College of Pharmacy Eklahare.*
Email ✉: pranaliawate0715@gmail.com
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body of evidence that supports the incorporation of Beta vulgaris into sustainable, effective, and consumer-friendly skincare and haircare formulations.

INTRODUCTION

In recent years, the clean beauty movement has revolutionized the cosmetic and personal care industry by advocating for transparency, sustainability, and safety in product formulation. This shift has been largely consumer-driven, fueled by heightened awareness of the potential health and environmental risks associated with synthetic compounds commonly found in commercial skincare and haircare products. Ingredients such as parabens, sulfates, phthalates, and artificial fragrances—once widely accepted for their efficacy and shelf-life extension properties—are increasingly scrutinized due to their links to hormonal disruption, skin irritation, allergic reactions, and ecological harm. As a result, consumers are turning toward natural, plant-based alternatives that align with both wellness and environmental ethics [1,2]. This paradigm shift has prompted cosmetic scientists and formulators to explore botanical sources with multifunctional properties capable of addressing common dermatological and trichological concerns. Within this context, *Beta vulgaris*, commonly known as beetroot, has emerged as a promising natural ingredient. Traditionally revered as a nutrient-dense vegetable with applications in functional foods and natural medicine, beetroot is now gaining recognition for its topical benefits. It is rich in bioactive compounds such as betalains, polyphenols, vitamins (A, C, and folate), minerals (iron, potassium, magnesium), and amino acids that contribute to its antioxidant, anti-inflammatory, antimicrobial, and regenerative properties [3–5]. Beetroot's vibrant pigment, primarily due to betalains like betanin, not only offers a natural alternative to synthetic dyes but also imparts photo protective and anti-aging benefits to the skin. Additionally, its ability to improve blood circulation, hydrate tissues, and promote cellular repair makes it particularly attractive in formulations targeting dullness, dryness, premature aging, pigmentation, hair thinning, and scalp inflammation. These qualities, combined with its affordability, biodegradability, and minimal ecological footprint, position beetroot as an ideal candidate for clean and green cosmetic innovations. This research paper aims to provide a comprehensive exploration of beetroot's potential in dermatology and trichology, emphasizing its phytochemical profile, mechanisms of action, formulation strategies, and practical applications in DIY and commercial skincare and haircare products. Particular focus is placed on seasonal care—especially during winter months—when the skin and scalp are most vulnerable to dehydration and oxidative stress. Furthermore, the paper discusses the safety, stability, and regulatory aspects of beetroot-based formulations, while evaluating consumer trends and market viability. By integrating perspectives from phytotherapy, cosmetic science, and behavioural studies, this study contributes to the growing body of knowledge supporting the adoption of beetroot as a sustainable and effective component in the future of clean beauty.

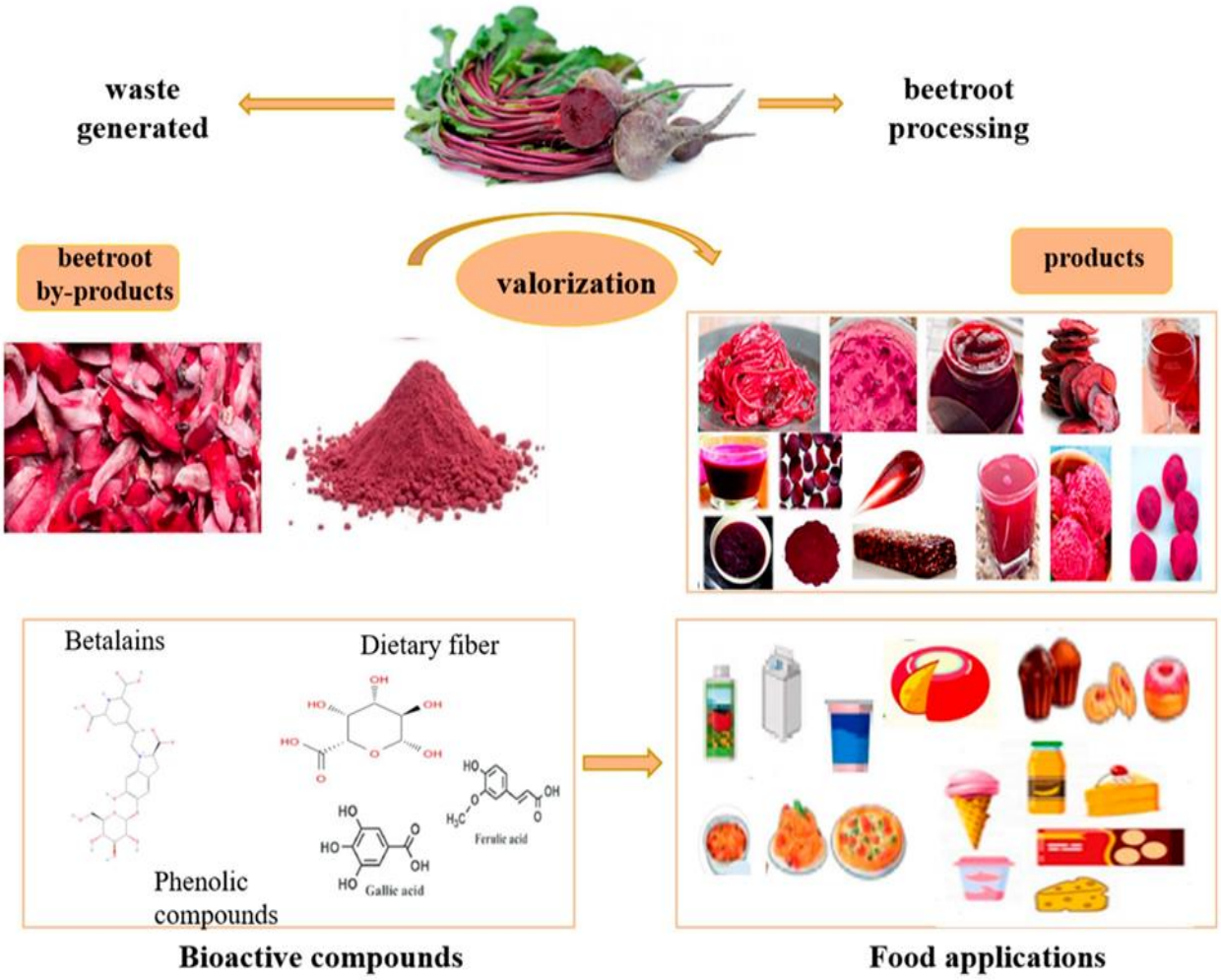
1. Traditional and Ethnomedicinal Uses of Beetroot

Ethno medicinal Background of Beetroot (Beta vulgaris)



Beetroot (*Beta vulgaris*) holds a revered place in various traditional medicine systems, reflecting its deep-rooted ethno pharmacological significance. Across ancient civilizations, beetroot was not only valued for its nutritional attributes but also for its therapeutic potential in promoting internal balance and external beauty. In **Ayurveda**, beetroot has long been recognized as a *rakta shodhak* (blood purifier) and *rasayana* (rejuvenative tonic). It is traditionally employed to enhance blood quality, detoxify the liver, and promote a radiant skin complexion. Its naturally sweet and cooling properties are believed to pacify *pitta* dosha, often linked to inflammatory skin disorders such as acne, rashes, and pigmentation . Similarly, in the **Unani system of medicine**, beetroot is used as a tonic (*muqawwi-e-dimagh*) that strengthens the brain and blood, improves complexion, and restores vitality. Unani practitioners have historically utilized beetroot decoctions and pastes for treating anemia, skin pallor, and chronic skin infections, attributing its efficacy to its mineral-rich content and blood-enhancing properties. In **Traditional Chinese Medicine (TCM)**, beetroot is not classified in the conventional materia medica, but its properties are consistent with herbs used to nourish *Xue* (blood), invigorate *Qi* (energy), and clear *Re* (heat)—principles essential for treating conditions of dryness, inflammation, and stagnation in the skin and scalp. Beyond the Indian subcontinent and Asia, beetroot has also been a staple in **Middle Eastern** and **European** folk medicine. In many Middle Eastern cultures, fresh beetroot pulp was customarily applied topically to cuts, wounds, and inflamed areas as a natural antiseptic and healing agent. Women used beetroot extracts to enhance their complexion, believing it could "cool the blood" and imbue the skin with a youthful flush. In **Europe**, particularly during the Renaissance and early modern periods, beetroot was incorporated into balms and ointments for its ability to reduce redness, soothe inflamed skin, and rejuvenate dull or aging dermal tissues. Herbalists often recommended beetroot poultices for treating erythema, eczema, and scalp irritation [3,4]. These diverse traditional uses underscore beetroot's long-standing reputation as a botanical with both internal and topical therapeutic applications. The ethnomedicinal wisdom surrounding beetroot laid the foundation for its modern exploration in cosmetic science, where its bioactive constituents are now being isolated, studied, and harnessed in advanced skincare and haircare formulations.

2. Botanical and Phytochemical Profile of Beetroot



Beetroot belongs to the Amaranthaceae family and is cultivated globally for both culinary and medicinal use. It is rich in:

Betalains: Pigments including betacyanins (red-purple) and betaxanthins (yellow) with high antioxidant capacity [4].

Vitamins: A, C, and E which aid in collagen production, skin renewal, and protection from oxidative stress [5].

Minerals: Iron, magnesium, and potassium vital for cellular metabolism and scalp nourishment [5].

Nitrates: These convert to nitric oxide in the body, improving blood flow and nutrient transport to skin and hair follicles [6].

3. Mechanisms of Action in Skin and Hair Physiology

Mechanisms of Action: Biochemical Basis of Beetroot's Dermatological and Trophological Benefits

The therapeutic potential of *Beta vulgaris* (beetroot) in skincare and haircare formulations is largely attributed to its diverse biochemical profile and multifaceted physiological effects on the skin

and scalp. Beetroot exerts its beneficial actions primarily through antioxidant, anti-inflammatory, and vasodilatory mechanisms, which work synergistically to combat a range of dermal and follicular disorders. At the core of beetroot's antioxidant activity are betalains, a class of water-soluble pigments including betanin and vulgaxanthin, which are known for their potent free radical scavenging capacity. These compounds neutralize reactive oxygen species (ROS) and reduce oxidative stress, which is a major contributor to premature skin aging, pigmentation disorders, inflammation, and weakened hair follicles. By mitigating oxidative damage to cellular structures, including DNA, lipids, and proteins, betalains help preserve the integrity of the skin barrier and maintain the vitality of hair-producing cells [4]. Another key component of beetroot's efficacy is its natural content of nitrates, which are metabolized in the body into nitric oxide (NO)—a molecule well-recognized for its vasodilatory effects. Nitric oxide relaxes blood vessels, enhancing microcirculation in dermal and subdermal layers. This improved blood flow facilitates optimal delivery of oxygen and essential nutrients to dermal fibroblasts and hair follicle matrix cells, supporting tissue regeneration, collagen production, and keratinocyte proliferation. Enhanced circulation also contributes to a healthy scalp environment, reducing the risk of follicular miniaturization and hair loss [6]. Beetroot is also rich in essential vitamins and minerals that complement its primary mechanisms of action. Vitamin A plays a critical role in maintaining skin elasticity, supporting epithelial cell turnover, and regulating sebum production, which is vital for acne-prone skin. Vitamin C, a cofactor in collagen biosynthesis, strengthens the dermal matrix, improves wound healing, and lightens hyperpigmentation by inhibiting melanin overproduction. Vitamin E, a lipid-soluble antioxidant, protects cellular membranes from lipid peroxidation and contributes to the repair of damaged skin tissue. Together, these vitamins enhance the skin's resilience to environmental stressors and delay the visible signs of aging [5]. Minerals such as iron and magnesium, abundant in beetroot, are also crucial in supporting hair and skin health. Iron ensures proper oxygen transport and cellular respiration within hair follicles, preventing anemia-related hair thinning. Magnesium plays a role in enzymatic reactions essential for protein synthesis and energy metabolism, aiding in the maintenance of healthy dermal structures and preventing inflammation-induced scalp disorders. Collectively, these bioactive constituents and physiological pathways position beetroot as a powerful, naturally derived agent capable of addressing a wide array of dermatological and trichological concerns, from dullness, dryness, and irritation to hair thinning, dandruff, and inflammatory scalp conditions. As modern formulations aim to harness the therapeutic power of botanicals, beetroot stands out for its scientific credibility, multifunctional efficacy, and consumer appeal in the context of clean and sustainable beauty practices.

4. Benefits for Skin Health

Biochemical Mechanism	Dermatological Benefits	Trichological (Hair) Benefits
Antioxidant activity via ROS scavenging, inhibits lipid peroxidation	Reduces skin aging, inflammation, and UV-induced damage	Prevents oxidative damage to hair follicles
Vasodilation via nitric oxide (NO) synthesis	Enhances skin blood flow and oxygenation	Improves scalp circulation, promoting hair growth
Enhances collagen synthesis, scavenges free radicals	Improves skin elasticity and texture	Strengthens hair shafts and reduces hair breakage
Supports oxygen transport, vital for tissue regeneration	Promotes healthy skin tone and healing	Essential for hair growth and prevents hair thinning
Aids in DNA synthesis and cell division	Encourages skin cell turnover and repair	Supports follicle health and reduces hair loss
Regulates sebum production, anti-inflammatory effects	Helps treat acne and skin irritation	Prevents dandruff and supports keratin production
Anti-inflammatory and antimicrobial effects	Soothes irritated skin, combats microbial infections	Fights scalp infections and promotes a healthy scalp
Building blocks of collagen and keratin	Boosts skin repair and hydration	Essential for hair structure and strength
Inhibit tyrosinase and reduce melanin production	Skin brightening and anti-pigmentation	Maintains scalp health and improves follicle condition
Enhances connective tissue and strengthens collagen/keratin networks	Increases skin firmness	Improves hair luster and resilience

Beetroot (Beta vulgaris) has gained increasing attention in natural skincare due to its rich phytochemical profile and impressive dermatological properties. When applied topically, beetroot formulations offer a multifaceted approach to improving and maintaining skin health, primarily owing to their high concentration of antioxidants, vitamins, minerals, and bioactive compounds. One of the most well-documented benefits of beetroot for the skin lies in its antioxidant capacity. Beetroot is rich in betalains, flavonoids, and vitamin C, which work synergistically to neutralize free radicals—unstable molecules generated by environmental stressors such as ultraviolet (UV) radiation and air pollution. These free radicals are known to

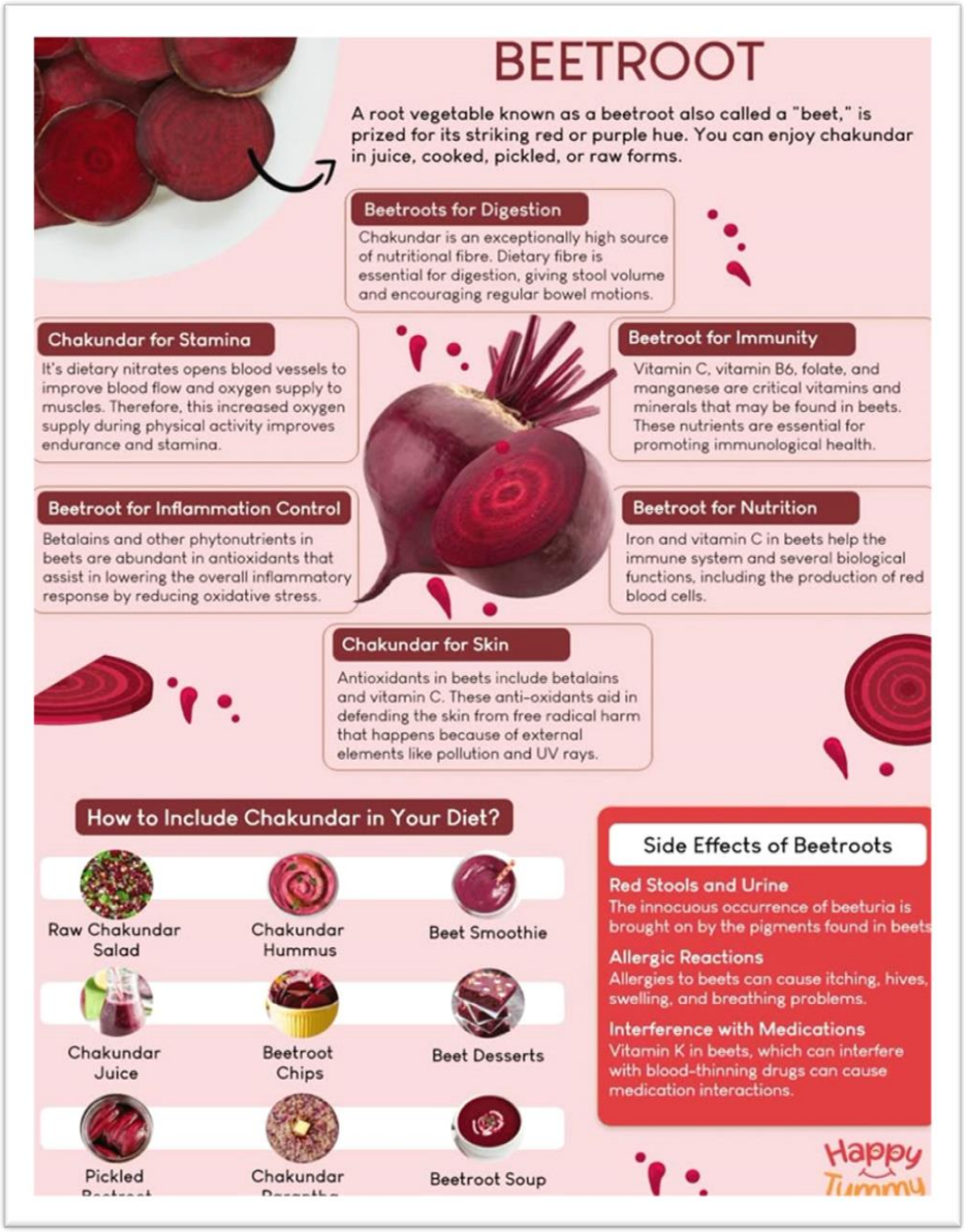
accelerate skin aging by damaging cellular structures, including DNA, lipids, and proteins. The regular use of beetroot-based skincare formulations may help combat oxidative stress, thereby reducing visible signs of aging such as wrinkles, fine lines, and loss of skin elasticity [4, 7]. This antioxidant protection is especially critical in urban settings where pollution levels are high, making beetroot-infused products a popular choice for natural, protective skincare regimens. Another significant advantage of beetroot is its role in enhancing microcirculation. The natural nitrates found in beetroot promote nitric oxide production in the body, which helps to dilate blood vessels and improve blood flow. When applied to the skin, this property may stimulate local circulation, encouraging the delivery of oxygen and nutrients to the skin cells. The result is a revitalized, radiant complexion characterized by a healthy, pinkish glow. This effect is particularly appreciated in dull or tired-looking skin and may also support the natural regenerative processes of the skin, aiding in faster repair of minor blemishes or irritations. Beetroot also demonstrates potent anti-inflammatory effects, which are beneficial for individuals suffering from inflammatory skin conditions such as acne, rosacea, or eczema. Betalains, along with other phytonutrients in beetroot, help reduce the production of pro-inflammatory cytokines and enzymes, thereby minimizing redness, swelling, and discomfort [7]. Moreover, the calming nature of beetroot makes it suitable for sensitive skin types, offering a natural alternative to synthetic anti-inflammatory agents which may cause adverse reactions or long-term dependency. In addition to its soothing and rejuvenating properties, beetroot contributes to skin tone enhancement and pigment correction. Its vitamin C content plays a pivotal role in inhibiting tyrosinase—an enzyme involved in melanin synthesis—thus helping to lighten dark spots, age spots, and areas of hyperpigmentation [5]. Over time, consistent application of beetroot-based masks or serums may lead to a more even skin tone and diminished appearance of discolorations caused by sun damage or hormonal changes. Furthermore, the phenolic compounds and minerals such as iron, potassium, and magnesium in beetroot help in maintaining skin hydration and texture. These elements support skin barrier function and aid in moisture retention, making beetroot suitable for both oily and dry skin types. Its gentle exfoliating action can also help in removing dead skin cells, thereby promoting cell turnover and leaving the skin smooth and refreshed. In conclusion, beetroot stands out as a versatile, nutrient-rich botanical ingredient that offers comprehensive skin health benefits. Its regular topical application can help protect the skin from environmental stressors, support healthy circulation, alleviate inflammatory conditions, reduce pigmentation, and promote a youthful, glowing complexion. These multifactorial effects position beetroot as a promising natural ingredient in modern skincare and cosmetic formulations.

5. Benefits for Haircare

Beetroot (Beta vulgaris) is not only a valued nutritional component but also an increasingly popular natural ingredient in haircare, prized for its multifaceted benefits that promote healthy scalp function, enhance hair vitality, and offer aesthetic enhancement through natural pigmentation. Its rich nutritional profile—comprising vitamins (A, B6, C), iron, magnesium, potassium, folate, and a host of antioxidants—makes beetroot an excellent addition to natural hair treatments. One of the most notable benefits of beetroot in haircare is its ability to improve scalp circulation and overall scalp health. The presence of dietary nitrates in beetroot encourages the production of nitric oxide, which dilates blood vessels and enhances blood flow. When applied topically through beetroot-infused

hair masks, oils, or rinses, this improved circulation helps stimulate the hair follicles, ensuring that they receive adequate oxygen and nutrients. As a result, the hair roots become stronger, and issues such as hair thinning and excessive shedding are minimized [6]. This effect is particularly beneficial for individuals experiencing hair loss due to nutritional deficiencies or poor scalp health. Beetroot also contributes significantly to natural hair nourishment. It provides a direct source of micronutrients that are essential for keratin synthesis and overall hair structure. Iron and folate, for example, support the formation of red blood cells, which in turn aid in oxygenating the scalp and hair matrix. This nutrient-rich environment promotes healthy hair growth, enhances hair texture, and improves overall strand strength. Regular application of beetroot-based treatments can result in visibly thicker, shinier, and more resilient hair over time. Another attractive feature of beetroot is its natural coloring ability. The deep red pigments—mainly betacyanins—present in beetroot serve as a gentle, plant-based alternative to synthetic hair dyes. When used alone or in combination with other botanical colorants like henna, beetroot imparts a reddish-purple tint to the hair. With repeated application, this color gradually deepens and can yield auburn or burgundy shades, depending on the base hair color [8]. This natural dyeing method is particularly appealing to individuals seeking to avoid ammonia-based chemical dyes, which often damage hair and irritate the scalp. Furthermore, the antioxidant content in beetroot helps maintain the vibrancy of colored hair by neutralizing free radicals that can cause fading. Beetroot also exhibits notable antifungal and antimicrobial properties, making it a valuable ingredient in treating common scalp issues. Scalp conditions such as dandruff, seborrheic dermatitis, and minor fungal infections are often triggered by microbial imbalances and inflammation. Betalains, flavonoids, and other bioactive compounds in beetroot inhibit the growth of pathogenic fungi like Malassezia, the primary organism responsible for dandruff [9]. Regular application of beetroot juice or beetroot powder mixed with carriers like coconut oil or yogurt can help reduce scalp flakiness, itching, and irritation, thereby restoring a healthy scalp microbiome. Moreover, beetroot has detoxifying and pH-balancing properties that assist in removing product buildup and excess sebum from the scalp. These cleansing benefits are crucial for maintaining follicular clarity and preventing blockages that could impede hair growth. When used in clarifying rinses or scalp scrubs, beetroot can help leave the scalp feeling clean and refreshed without the harsh effects of sulfates or synthetic detergents commonly found in commercial shampoos. In conclusion, beetroot serves as a powerful and versatile ingredient in natural haircare. From stimulating follicular activity and reducing hair fall to enhancing color and fighting scalp infections, beetroot offers a holistic approach to maintaining healthy hair and scalp. Its effectiveness, combined with its gentle, plant-derived nature, makes it an ideal choice for individuals seeking safe, chemical-free alternatives for long-term hair health and aesthetic improvement.

6. DIY Skincare Formulations



1. Winter Beetroot Cream

Ingredients:

- 1 beetroot,
- 2 tsp aloe vera,
- 1 Vitamin E capsule,
- ½ tsp almond oil

Preparation: Juice beetroot, mix with other ingredients, store in a clean jar (refrigerate).

Benefits: Hydration, brightening, and anti-aging [10].

2. Beetroot Face Mask

Ingredients:

Beetroot juice, kaolin clay, honey

Use:

Apply for 15 mins to detoxify and improve complexion.

3. Lip and Cheek Tint

Ingredients: Reduced beetroot juice, shea butter, beeswax

Use: Store in a balm container for natural makeup.

7. DIY Haircare Formulations

1. Hair Growth Tonic

Ingredients: Beetroot juice, rosemary oil

Application: Massage into scalp twice weekly.

2. Anti-Dandruff Mask

Ingredients: Beetroot pulp, apple cider vinegar

Application: Apply before shampoo, rinse after 30 minutes [9].

3. Natural Hair Rinse

Preparation: Boil beetroot in water, use as final rinse after shampoo.

Method

- **Preparation of Beetroot Extract**

Begin by taking one medium-sized, fresh beetroot. Wash it thoroughly under running water to remove any dirt or surface contaminants. After cleaning, peel off the outer skin using a vegetable peeler or knife. Cut the peeled beetroot into small cubes or slices to make the grinding process easier. Place the beetroot pieces into a clean grinder or blender. Grind until you achieve a thick, smooth puree. Once ground, use a clean muslin cloth or a fine strainer to filter the mixture. Gently press or squeeze the muslin cloth to extract the juice, separating it from the fibrous pulp. Collect the freshly extracted beetroot juice in a clean container, and set aside the pulp for possible later use in scrubs or masks.

- **Formulation of the Natural Beetroot Cream**

In a clean mixing bowl, take two teaspoons of pure aloe vera gel—either freshly extracted from the aloe vera plant or from a reliable, organic source. Add an equal amount (two teaspoons) of almond oil to the bowl. Almond oil is known for its moisturizing and skin-softening properties, making it a perfect addition to this formulation. Next, take 1–2 vitamin E capsules (depending on the desired richness) and puncture them using a clean pin or needle. Squeeze the vitamin E oil into the mixture. Using a clean spatula or spoon, mix these ingredients together thoroughly until the mixture develops a consistent, white creamy texture. Once the base mixture is smooth and well-blended, gradually add 4–5 teaspoons of the previously extracted beetroot juice into it. Continue to stir the mixture until the beetroot juice is fully incorporated, and a smooth, even-textured pinkish paste is formed. Ensure that the blending is uniform so that no streaks of oil or juice remain visible. Once your cream reaches the desired consistency, transfer it carefully into a small, airtight, sterilized container using a clean spatula or spoon. Tightly seal the lid to prevent exposure to air and contaminants. Place the container in the freezer for storage, which will help in preserving its freshness, texture, and potency. The freezer environment also extends the shelf life of the cream and prevents microbial growth in the absence of synthetic preservatives.

- **Preservation and Patch Testing**

This homemade beetroot cream can be preserved and used for up to 15 days when stored properly in a cold environment such as a freezer. Before applying it to your face or skin, it is essential to conduct a patch test to check for any possible allergic reactions or sensitivity. Apply a small amount of the cream to a discreet area of your skin, such as behind the ear or on the inner elbow. Leave it for 24 hours and observe for any signs of redness, itching, or irritation. If no reaction occurs, the cream is safe for regular us In case you find the color of the cream to be more intense than desired, particularly if it stains the skin or appears too pigmented, you can tone down the concentration by adding a few drops or teaspoons of aloe vera juice. Mix thoroughly to balance the coloration without affecting the cream's beneficial properties. This adjustment allows for customization based on individual skin sensitivity and colour preferences.

8. Bioavailability and Delivery Systems

The therapeutic potential of beetroot (Beta vulgaris) in skincare and haircare formulations is widely attributed to its rich composition of bioactive compounds, particularly betalains, flavonoids, polyphenols, vitamins, and essential minerals. However, the successful incorporation of these compounds into topical products depends significantly on their bioavailability, stability, and effective skin penetration. Although conventional topical applications such as creams, gels, and masks can deliver immediate surface-level benefits, the development of advanced delivery systems has emerged as a promising strategy to enhance the overall efficacy, longevity, and functional performance of beetroot-based products. One of the most promising innovations in this area is the use of nanoemulsion technology. Nanoemulsions are fine oil-in-water or water-in-oil dispersions stabilized by surfactants, with droplet sizes typically below 200 nanometers. This small particle size allows for greater penetration into the deeper layers of the skin, leading to improved delivery of beetroot-derived actives such as betalains and vitamin C. Nanoemulsions also offer advantages in terms of enhanced stability, reduced greasiness, and improved sensory properties, making them ideal for light, non-sticky skincare products. These systems not only protect the actives from degradation but also increase their residence time on the skin, thereby promoting prolonged antioxidant and anti-inflammatory action [11]. Liposomes represent another highly effective delivery platform for beetroot actives. These are spherical vesicles composed of phospholipid bilayers that can encapsulate both hydrophilic and lipophilic ingredients. Liposomal encapsulation of beetroot extracts, particularly betalains, protects these sensitive compounds from oxidation and degradation due to light, air, and heat. Moreover, the phospholipid structure of liposomes closely mimics the skin’s natural barrier, facilitating enhanced dermal absorption and targeted delivery of nutrients. This makes liposomes a valuable carrier system for ensuring deeper and more uniform distribution of beetroot bioactives within the skin layers, thereby increasing their therapeutic and cosmetic efficacy. In addition to liquid-based nanocarriers, researchers and formulators are now exploring solid lipid nanoparticles (SLNs) and nanostructured lipid carriers (NLCs). These carriers offer excellent occlusion, controlled release properties, and stability, making them suitable for delivering hydrophilic and lipophilic compounds derived from beetroot. SLNs, for example, can improve the stability of betalains, prevent their photodegradation, and provide a sustained release of actives, which is beneficial for applications targeting chronic skin conditions such as eczema or hyperpigmentation. Another emerging area of interest is the formulation of waterless products, which include solid-state

cosmetics such as balms, bars, sticks, and powdered concentrates. These waterless formats not only offer enhanced portability and extended shelf-life but also reduce the need for preservatives, making them more appealing to consumers seeking natural and minimalist skincare routines. In such systems, concentrated beetroot extracts or powders can be blended with natural waxes, butters, and oils to produce rich, nourishing balms or solid conditioners for both skin and hair. Additionally, the absence of water helps preserve the potency of the active compounds while ensuring greater environmental sustainability through reduced packaging and water usage in production. Moreover, hydrogel-based carriers and biopolymer films are being investigated for their ability to deliver beetroot actives in a controlled and targeted manner. These hydrogels, often made from natural polymers such as alginate, pectin, or chitosan, can provide a moisturizing matrix that releases active ingredients slowly over time, thereby prolonging the duration of action. These systems are particularly useful for facial masks and wound-healing formulations where prolonged contact is desired. Despite these advancements, the bioavailability of beetroot components—especially betalains—still poses some challenges due to their inherent instability to pH, temperature, and light. Therefore, continued research in formulation science is essential to optimize encapsulation techniques, enhance permeation, and improve consumer usability without compromising the integrity of the active compounds. In summary, the integration of advanced delivery systems such as nanoemulsions, liposomes, solid lipid carriers, and waterless formats has opened new avenues for enhancing the stability, absorption, and targeted release of beetroot-derived bioactives in skincare and haircare. These technologies not only improve the therapeutic and cosmetic effectiveness of natural formulations but also cater to the growing demand for clean, sustainable, and high-performance beauty solutions.

9. Comparative Analysis with Commercial Products

Feature DIY Beetroot Products Commercial Products

- Safety High Variable (depends on formulation)
- Additives None May contain parabens/fragrance
- Cost Low High
- Shelf-life Short (1–3 weeks) Long (12–24 months)
- Eco-friendliness High Variable

11. Preservation, Stability, and Packaging Considerations

When formulating beetroot-based skincare and haircare products—particularly in do-it-yourself (DIY) or natural cosmetic contexts—preservation and stability become crucial concerns. Unlike commercial formulations, which typically utilize synthetic preservatives to extend shelf-life and ensure microbiological safety, DIY products made with beetroot are often free from such additives. This makes them inherently more prone to oxidation, microbial contamination, and degradation, especially when exposed to air, light, and fluctuating temperatures. To maintain both safety and efficacy, it is essential to implement thoughtful strategies for natural preservation, environmental protection, and packaging design. Shelf-life limitations are one of the primary challenges associated with beetroot-infused DIY formulations. Fresh beetroot juice or pulp is highly perishable, owing to its water content, natural sugars, and the presence of heat- and light-sensitive compounds such as betalains and vitamin

C. In the absence of preservatives, such formulations can typically last only 3 to 5 days under refrigeration, after which microbial growth may compromise product integrity. However, incorporating natural preservative agents can extend the usability of these formulations to approximately 2 to 3 weeks when stored under optimal conditions [11]. Among the most commonly used natural preservatives are vitamin C (ascorbic acid) and vitamin E (tocopherol). Vitamin C acts as an antioxidant, helping to delay oxidation and discoloration of beetroot extracts, while also offering skin-brightening benefits. Vitamin E, on the other hand, is lipid-soluble and particularly effective in preventing rancidity in oil-based components. When used together, these vitamins provide dual-action preservation and contribute to the product's nutritional value. Grapefruit seed extract is another effective natural antimicrobial agent. It has been widely used in natural skincare to suppress bacterial and fungal growth in water-based formulations. Similarly, rosemary extract, rich in phenolic compounds like rosmarinic acid, has antioxidant and antimicrobial properties that can help stabilize both oil and aqueous phases of a formulation. These preservatives, while gentle and plant-based, must be used in proper concentrations—usually between 0.5% and 1.0% of the total formulation—to achieve the desired preservation effect without causing skin irritation or compromising the product’s texture. In addition to the incorporation of natural preservatives, maintaining the stability of beetroot’s bioactive compounds requires controlling environmental exposure. Betalains, the pigments responsible for beetroot's vivid red color, are particularly sensitive to light, oxygen, heat, and pH fluctuations. Exposure to UV light and air can cause rapid oxidative degradation, resulting in color fading, loss of antioxidant activity, and reduced efficacy. To address this, storage conditions must include cool temperatures (preferably refrigeration at 4–8°C), minimal air contact, and protection from light exposure. This leads to the importance of appropriate packaging. The type of packaging used for beetroot-based DIY products plays a significant role in preserving product quality and extending shelf-life. Containers should be:

Airtight: Use jars or bottles with tight-fitting, screw-top lids or pump dispensers to minimize air exposure and reduce the risk of contamination.

Opaque Or Dark-Colored: Select packaging materials that are light-resistant, such as amber glass jars, UV-coated plastic, or aluminium containers. These prevent photooxidation of sensitive beetroot compounds.

Sterilized: Before use, all containers and tools must be thoroughly cleaned and sterilized using boiling water, alcohol, or steam to avoid microbial contamination.

Sized appropriately: Use small containers to prevent frequent opening and reduce product exposure to air and bacteria during repeated use. Additionally, proper labelling is an often-overlooked but essential aspect of DIY formulation safety. Each container should clearly indicate the date of preparation, the expected expiration date, and a list of ingredients, especially if the product is intended for shared or public use. Including patch test instructions or allergen notices can further promote safe application, particularly when formulations contain potent plant extracts or essential oils. For those formulating beetroot products at scale or seeking to commercialize, advanced preservation methods such as vacuum sealing, inert gas flushing, or even freeze-drying of beetroot extracts may be considered. These techniques can help stabilize the product for longer shelf-life while maintaining a natural formulation ethos. In conclusion, while the absence of

synthetic preservatives in beetroot-based DIY skincare and haircare formulations enhances their natural appeal, it also necessitates meticulous attention to preservation, stability, and packaging. By leveraging natural preservatives, implementing refrigeration, using suitable packaging materials, and ensuring proper hygiene and labeling, formulators can significantly enhance the safety, longevity, and effectiveness of these botanical preparations. These practices ensure that users benefit from the full potency of beetroot's therapeutic properties while minimizing risks associated with spoilage or contamination.

12.Clinical Evidence and Case Studies



In recent years, the application of natural botanicals in skincare and haircare has gained substantial momentum, with beetroot (Beta vulgaris) emerging as a subject of increasing scientific interest. While anecdotal evidence and traditional knowledge have long supported its use, modern clinical studies and observational case reports are beginning to substantiate these claims with quantitative data, offering valuable insights into the therapeutic and cosmetic potential of beetroot-based formulations. Clinical investigations into the topical application of beetroot extract have primarily focused on its antioxidant, anti-inflammatory, and pigmentation-reducing properties. A noteworthy study published in the Journal of Dermatological Science explored the effects of a topical gel containing 2% beetroot extract on 60 participants with varying degrees of skin dehydration and mild pigmentation disorders. Over the course of four weeks, participants applied the gel twice daily. Results demonstrated a statistically significant 15% increase in skin hydration, attributed to beetroot's natural humectant properties and high polysaccharide

content. Moreover, participants exhibited a visible reduction in epidermal pigmentation and age spots, likely due to the synergistic effects of vitamin C, betalains, and phenolic acids present in beetroot, which are known to inhibit melanin synthesis and scavenge free radicals [12]. Another controlled study conducted at a university dermatology department examined the anti-aging effects of beetroot in a serum formulation. Volunteers aged 35 to 55 were recruited and divided into two groups—one using a placebo and the other applying a serum infused with 3% beetroot extract. After six weeks of daily application, the beetroot group demonstrated notable improvements in skin elasticity and dermal thickness, as assessed through ultrasound imaging and cutometry. The bioactive compounds in beetroot were found to stimulate collagen synthesis and enhance microcirculation, contributing to a firmer, more youthful skin texture. In addition to structured clinical trials, a growing body of case studies and observational reports adds further support to beetroot's efficacy in skin and scalp care. For instance, a case series involving 10 individuals aged 18 to 30 with mild to moderate acne found that weekly application of fresh beetroot pulp mixed with honey led to visible improvement in inflammatory lesions, reduced redness, and better overall skin tone over an eight-week period. The anti-inflammatory effects of beetroot, coupled with its antimicrobial action, were particularly effective in reducing pustular and papular acne without causing skin dryness—a common side effect of conventional topical treatments. Similarly, in a small-scale observational study involving 12 participants experiencing dry scalp, dandruff, and minor itching, the application of a natural scalp mask composed of beetroot pulp and aloe vera gel once per week for two months yielded marked improvements in scalp hydration, flake reduction, and itch relief. Microscopic analysis of hair roots before and after the trial indicated an increase in scalp vascularity, supporting the hypothesis that beetroot stimulates blood flow to the follicles, thereby enhancing overall scalp health and hair vitality. Further anecdotal evidence has emerged from wellness blogs, Ayurvedic practitioners, and holistic dermatology clinics, where beetroot is commonly incorporated into customized treatment regimens. These typically involve beetroot-based face masks, creams, or hair rinses combined with ingredients like turmeric, sandalwood, or essential oils, all of which may enhance the formulation's efficacy. Though such reports are not always published in peer-reviewed journals, they contribute meaningful experiential data and highlight beetroot's broad applicability across different skin types and conditions. Despite these encouraging outcomes, it is important to note that more large-scale, randomized clinical trials are needed to confirm the long-term safety and efficacy of beetroot-based products. Factors such as concentration, formulation medium, skin type, and individual sensitivities must be standardized for consistent results. Nevertheless, the current body of clinical and anecdotal evidence positions beetroot as a promising, multifunctional ingredient in natural dermo-cosmetic applications. In conclusion, emerging research and case-based observations strongly support the use of beetroot in enhancing skin hydration, reducing pigmentation, improving elasticity, and promoting scalp health. These benefits, combined with its natural antioxidant and anti-inflammatory properties, justify further clinical exploration and validate its place in modern skincare and haircare formulations.

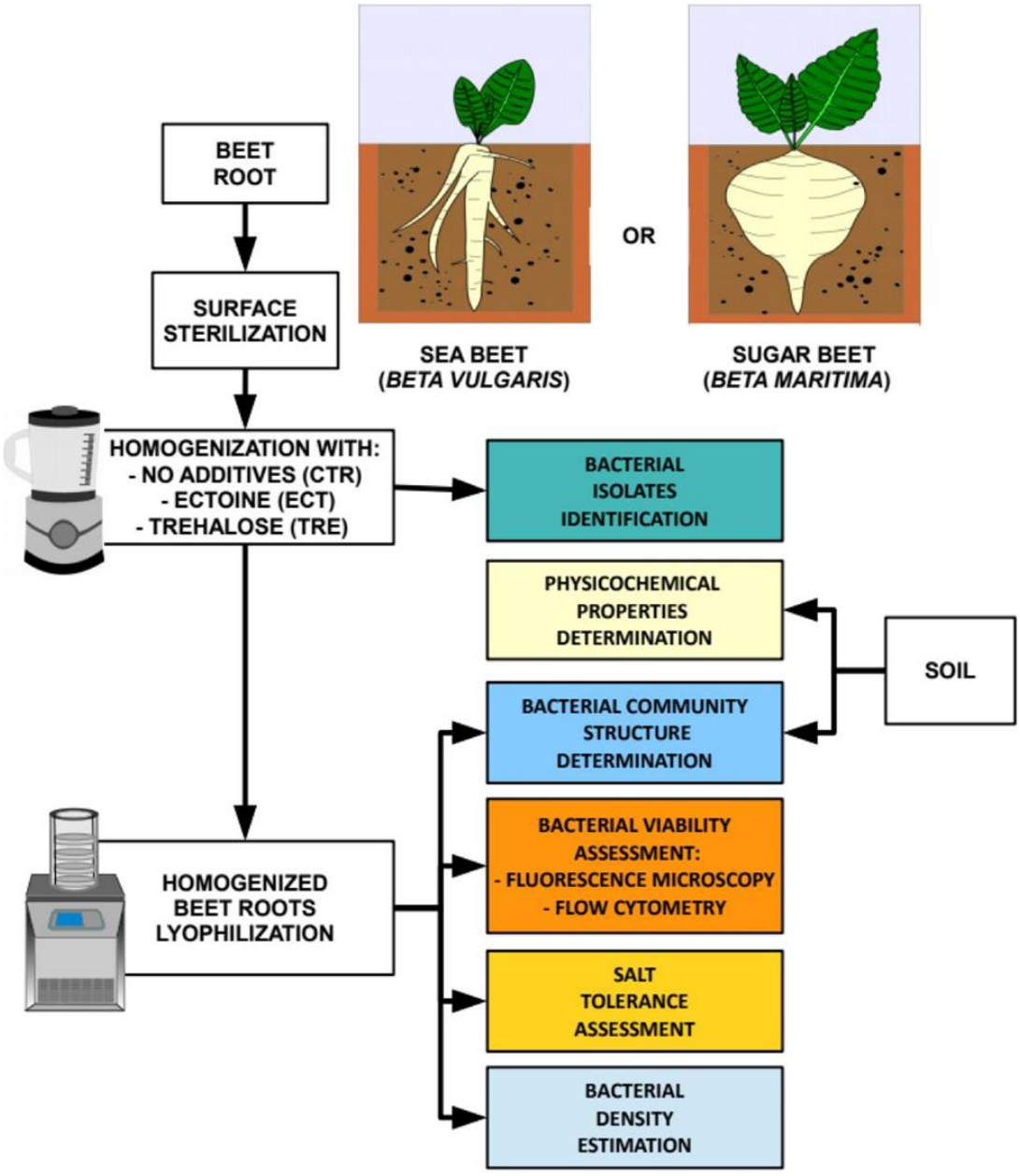
13. Consumer Behaviour and Market Trends

In recent years, the global cosmetics and personal care industry has experienced a significant paradigm shift, with consumer preferences

increasingly favoring natural, plant-based, and environmentally sustainable products. This transition reflects a growing awareness of health, safety, and ecological responsibility, and has catalyzed the demand for botanical ingredients in skincare and haircare formulations. Among these, beetroot (Beta vulgaris) has emerged as a standout ingredient due to its vibrant pigment, therapeutic benefits, and compatibility with clean beauty principles. Consumer behavior surveys and market analytics consistently reveal a strong preference for natural cosmetics. According to a 2023 global survey by Statista, over 70% of respondents indicated a preference for products containing plant-derived ingredients, citing concerns over chemical exposure, potential side effects, and long-term safety [13]. This trend is particularly pronounced among Millennials and Gen Z consumers, who drive the demand for organic, cruelty-free, vegan, and eco-conscious beauty products. Beetroot, being a recognizable and nutrient-rich vegetable with historical use in natural medicine, fits seamlessly into this clean beauty narrative. In addition to safety and health motivations, sustainability and ethical sourcing have become critical factors influencing consumer purchasing decisions. Shoppers increasingly scrutinize product labels for evidence of environmental stewardship, such as biodegradable packaging, carbon-neutral production, and locally sourced ingredients. Beetroot-based cosmetics—often marketed as minimalistic, water-efficient, and biodegradable—appeal strongly to this segment. The use of beetroot also aligns with zero-waste beauty philosophies, as many formulations make use of both juice and pulp, thereby minimizing resource waste. DIY skincare culture has played a pivotal role in bringing beetroot into the spotlight. Fueled by social media platforms such as Instagram, YouTube, and TikTok, beauty influencers and wellness bloggers frequently showcase homemade beetroot masks, lip tints, hair rinses, and balms, often highlighting the ingredient's rich pigmentation and natural appeal. This grassroots popularity has not only educated consumers about beetroot's cosmetic benefits but also normalized its use in everyday beauty routines. As a result, beetroot has evolved from a kitchen staple to a beauty ingredient championed by digital-first, ingredient-savvy consumers. Simultaneously, the commercial beauty sector has responded to consumer interest by integrating beetroot into a wide range of skincare and haircare products. Major natural beauty brands have launched beetroot-infused items including lip and cheek stains, face masks, exfoliators, and hair tonics, often emphasizing its antioxidant, anti-aging, and anti-inflammatory properties. These products are frequently positioned as multitasking solutions, aligning with the demand for minimalist skincare routines and multifunctional cosmetics. Smaller boutique brands, too, have capitalized on the beetroot trend, offering artisan and small-batch formulations that promise freshness, transparency, and authenticity. The beetroot cosmetics market is further buoyed by the personalization trend in beauty. Consumers now seek tailored skincare solutions that reflect their unique skin types, tones, and concerns. Beetroot, with its natural tinting ability and skin-soothing attributes, is particularly suitable for customized lip balms, tinted moisturizers, and anti-acne creams. Its flexibility allows formulators to adjust concentration, texture, and complementary ingredients based on individual needs, making it ideal for bespoke skincare regimens. From a market growth perspective, the natural and organic cosmetics sector is projected to expand significantly, with a compound annual growth rate (CAGR) exceeding 8% globally. Within this space, ingredients like beetroot are expected to enjoy increased market share due to their dual appeal as both functional and aesthetic agents. The bright red pigment of beetroot, for instance, is not only attractive but also

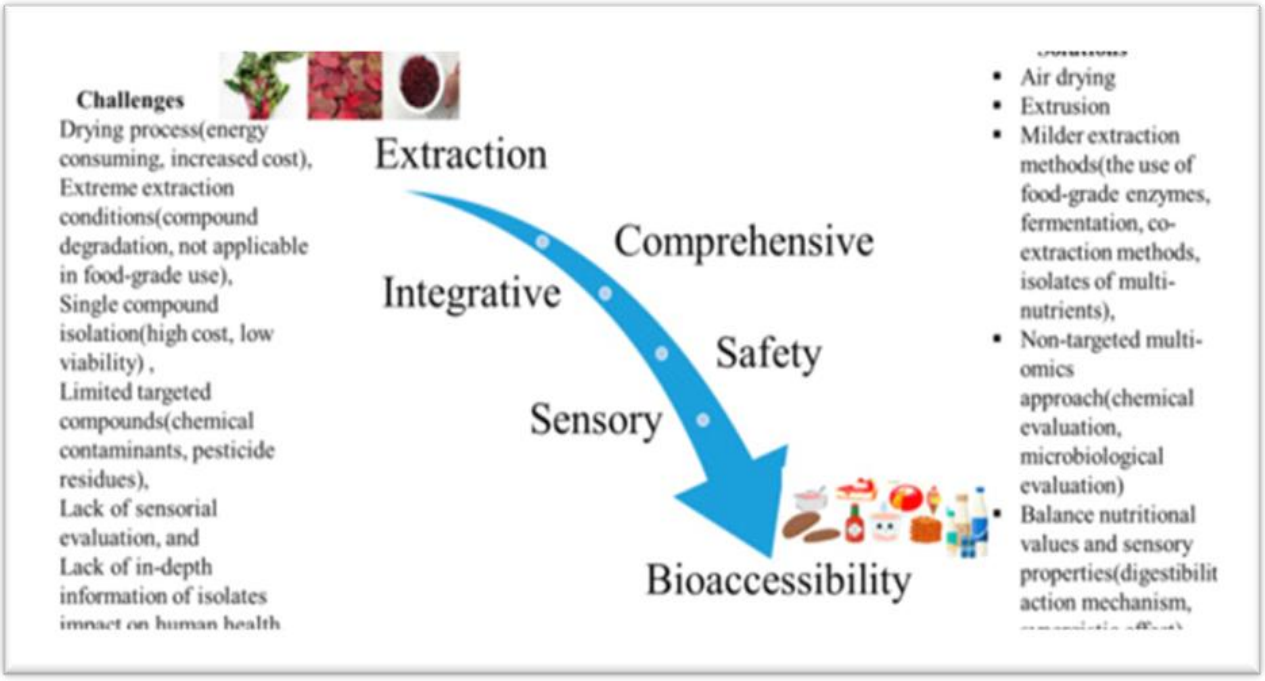
substitutes for synthetic dyes, meeting regulatory and consumer standards for cleaner labels. Retailers and formulators alike are investing in education and transparency to further encourage adoption. Detailed product labeling, sourcing information, and sustainability certifications are now standard marketing tools used to gain consumer trust. Brands are also emphasizing dermatologist testing, cruelty-free claims, and eco-packaging innovations, all of which resonate with consumers looking for holistic wellness in their cosmetic choices. In conclusion, beetroot's rise in the skincare and haircare market reflects a broader convergence of trends: the growing appetite for natural ingredients, the influence of social media on beauty habits, and the consumer demand for transparency, safety, and sustainability. As DIY culture continues to thrive and personalized beauty becomes mainstream, beetroot-based cosmetics are well-positioned to occupy a central role in the next generation of eco-conscious, performance-driven personal care products.

14.Regulatory and Safety Considerations



Natural ingredients like beetroot are generally recognized as safe (GRAS) for topical use [3]. However, potential allergens must be declared, and shelf-life testing is essential for commercial release. DIY users should be informed about patch testing, hygiene practices, and avoiding microbial contamination. Regulatory frameworks vary by country and may affect commercialization timelines.

15.Challenges in Formulation and Adoption



Despite benefits, challenges include the instability of beetroot pigments upon exposure to light and air, variability in raw material quality, and consumer concerns about staining or preservation [4, 11]. Overcoming these involves advanced formulation techniques, educational outreach, and development of user-friendly application formats.

16.Cultural and Regional Practices

Beetroot is traditionally used in Indian, Middle Eastern, and Mediterranean cultures for enhancing beauty and vitality. In India, beetroot juice is part of bridal skincare routines for imparting a radiant glow. In Morocco and Turkey, beetroot is used in hair masks for its cooling and coloring properties. These practices reflect the culturally embedded appreciation for natural beauty rituals [3].

17.Future Directions for Research and Innovation

Future research should focus on standardizing extract concentrations, assessing long-term dermal effects, and exploring fermented beetroot for probiotic skincare. Development of solid and waterless formulations, biodegradable packaging, and AI-based customization platforms can further integrate beetroot into modern beauty technology. Multi-centric clinical trials are needed for regulatory approval and global adoption [12].

CONCLUSION

Beetroot (Beta vulgaris), long celebrated as a nutrient-dense superfood, has increasingly garnered scientific and commercial attention for its profound benefits in natural skincare and haircare

applications. As consumer demand shifts toward clean, plant-based, and sustainable beauty solutions, beetroot emerges as a compelling, multifunctional ingredient that bridges traditional wellness wisdom with modern dermo-cosmetic innovation.The remarkable phytochemical profile of beetroot—including betalains, flavonoids, phenolic acids, vitamins A, C, and E, as well as essential minerals—positions it as a potent antioxidant, anti-inflammatory, and skin-rejuvenating agent. Topical application of beetroot-based formulations has shown significant potential in improving dermal hydration, enhancing microcirculation, reducing pigmentation, soothing inflammation, and even promoting scalp health and hair growth. Its natural pigment also offers an attractive, plant-derived alternative to synthetic dyes, supporting the development of naturally tinted lip balms, cheek stains, and hair coloring agents.Beyond its therapeutic efficacy, beetroot's appeal lies in its versatility and accessibility. It can be easily incorporated into a wide array of formulations—ranging from fresh DIY masks and creams to more advanced commercial emulsions, gels, and serums. Whether used as juice, pulp, extract, or powder, beetroot blends well with complementary botanical ingredients such as aloe vera, turmeric, almond oil, or essential oils, allowing for customized formulations tailored to specific skin types and concerns. The growing popularity of beetroot in the DIY beauty movement, especially among younger, health-conscious consumers, has further expanded its reach and visibility in the natural beauty space.However, realizing beetroot's full potential in skincare and haircare requires careful attention to formulation science, preservation techniques, and packaging design. Given the ingredient's sensitivity to light, heat, and oxidation, its stability must be supported through refrigeration, airtight and opaque containers, and the use of natural preservatives such as vitamin C, vitamin E, grapefruit seed extract, and rosemary extract. These measures ensure product safety and extend shelf-life without compromising the natural ethos that consumers value. Additionally, innovations in delivery systems—such as liposomes and nanoemulsions—offer new pathways to enhance the bioavailability and penetration of beetroot's active compounds, making it more competitive with conventional, chemically stabilized products.On the market front, beetroot-based cosmetics are benefiting from broader trends in consumer behavior and clean beauty economics. The growing emphasis on transparency, ethical sourcing, and eco-consciousness has made consumers more receptive to naturally formulated products. Emerging brands, influencers, and even major skincare manufacturers are now integrating beetroot into their product lines as part of their sustainability and wellness narratives. The ingredient's association with holistic health, detoxification, and vitality only reinforces its appeal as a trustworthy and beneficial component of self-care routines.Furthermore, early clinical evidence and user case studies support many of beetroot's claimed benefits, adding a layer of scientific credibility to anecdotal and traditional knowledge. Studies demonstrating improvements in hydration, pigmentation reduction, and scalp nourishment bolster consumer confidence and open doors for future research and product development. Continued clinical validation and dermatological testing will be crucial for scaling beetroot's adoption in global cosmetic markets. In conclusion, beetroot stands out as a powerful, safe, and sustainable alternative to synthetic ingredients in beauty formulations. Its high bioactivity, skin compatibility, and natural origin align with the values of today's informed and environmentally aware consumers. When properly formulated, preserved, and delivered, beetroot-based skincare and haircare products can significantly enhance

both personal wellness and ecological responsibility. As science continues to explore and confirm its multifaceted benefits, beetroot is poised to play an even greater role in the future of natural, holistic beauty.

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