# Ethnobotanical wisdom in phytocosmeceuticals: Investigating pharmacological applications in Western Odisha, India

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## Research

## Abstract

*Background:* Ethnobotany bridges traditional knowledge with modern science, focusing on the sustainable use of plants. Phytocosmetics, derived from plant-based bioactive compounds, offer eco-friendly alternatives to synthetic cosmetics. This research documents and analyzes tribal knowledge of phytocosmetics in western Odisha, identifying plant species, preparation methods, cultural significance, and potential for sustainable, eco-friendly cosmetic development.

*Methods:* An ethnobotanical survey was conducted across six districts in Western Odisha, engaging 112 tribal informants through semi-structured interviews and focus group discussions. Plant specimens were collected and identified, and their cultural and pharmacological uses were documented. Quantitative indices such as Use Value (UV), Relative Frequency of Citation (RFC), and Fidelity Level (FL) were used to analyze the data.

*Results*: A total of 39 plant species were obtained from 33 different families. Key plants identified include *Aloe barbadensis*, *Azadirachta indica*, *Curcuma longa*, and *Hibiscus rosa-sinensis*. These plants are commonly used in skin moisturizers, antimicrobial preparations, anti-aging formulations, and hair care products. Santalum album exhibited the highest UV (0.93) and RFC (0.98) values, while its FL (97%) underscored its strong association with anti-inflammatory and skin-conditioning applications. Other notable plants, such as Curcuma longa and Rubia tinctorum, demonstrated high FL values, reflecting their specific roles in skin brightening and rejuvenation. Their pharmacological properties are mediated through pathways such as NF-κB and Nrf2, supporting their efficacy in skincare and haircare.

*Conclusion:* The study highlights the relevance of traditional phytocosmetic practices in modern applications, emphasizing the importance of conservation and sustainable development. Integrating tribal knowledge with advanced technologies, such as nanotechnology, offers the potential for innovative, eco-friendly cosmeceuticals.

*Keywords:* Ethnobotany, Phytocosmetics, Western Odisha, Sustainable Development, Biodiversity Conservation.

## Background

Ethnobotany, the scientific exploration of the dynamic relationship between people and plants, is deeply rooted in traditional knowledge systems. It encompasses flora for medicine, food, cosmetics, rituals, and other cultural practices (Sultan *et al*. 2024). This discipline bridges indigenous practices with modern scientific applications, preserving the wisdom of ancient traditions while offering innovative solutions for sustainable development. In recent years, ethnobotany has gained significant recognition in developing phytocosmetics—cosmetic products derived entirely or predominantly from plant-based ingredients (Daroueche *et al*. 2024). These products, characterized by their natural origin, utilize the therapeutic properties of plants to enhance skin, hair, and overall well-being. As concerns over the potential health risks and environmental impact of synthetic chemicals in conventional cosmetics grow, phytocosmetics have emerged as a safer, more sustainable, and eco-friendly alternative (Khomsi *et al*. 2022).

Phytocosmetics derive their efficacy from the bioactive compounds found in plants, which exhibit diverse pharmacological properties. Alkaloids, flavonoids, saponins, tannins, phenolic acids, terpenoids, and essential oils play pivotal roles in their activity. Flavonoids, for instance, are renowned for their potent antioxidant properties, which protect skin cells from oxidative stress caused by environmental pollutants and ultraviolet radiation (SARI *et al*. 2024). This oxidative stress is a major contributor to premature aging, wrinkles, and pigmentation disorders. Conversely, tannins exhibit astringent properties, helping tighten pores, reduce acne, and manage excess sebum production. Saponins contribute to skin hydration and exhibit mild detergent properties, making them excellent for cleansing formulations. Terpenoids and essential oils, such as those derived from neem, sandalwood, and rosemary, exhibit antimicrobial, anti-inflammatory, and soothing properties, catering to sensitive or acne-prone skin (Ndhlala *et al*. 2022).

The pharmacological relevance of phytocosmetics extends to their ability to modulate skin physiology at the cellular and molecular levels. Many plant-derived compounds interact with skin receptors and signaling pathways to regulate inflammatory responses, enhance collagen synthesis, and promote skin repair (Nadeeshani *et al*. 2022). For example, phenolic compounds modulate the nuclear factor-kappa B (NF-κB) pathway, a key regulator of inflammation, thereby reducing redness and irritation. Similarly, compounds like curcumin from turmeric stimulate fibroblast activity, enhancing collagen production and skin elasticity (Pranskuniene *et al*. 2022). Additionally, plant sterols and fatty acids found in natural oils, such as coconut and argan oil, strengthen the skin barrier by replenishing lipids and preventing transepidermal water loss (Ijeabuonwu *et al*. 2024). Hair care formulations in phytocosmetics also benefit from the pharmacological properties of plant-derived compounds. Alkaloids and polyphenols promote hair growth by enhancing blood circulation in the scalp and stimulating hair follicle activity. Antioxidants protect hair keratin from oxidative damage, while antimicrobial agents address issues like dandruff and scalp infections. Henna, a traditional dye derived from *Lawsonia inermis*, contains lawsone, a compound that binds to keratin, imparting a natural hue while conditioning the hair (Gamage *et al*. 2021). Similarly, hibiscus extracts are rich in mucilage and organic acids that nourish the scalp and strengthen hair strands (Stebel 2022).

The western region of Odisha, known for its rich biodiversity and cultural heritage, is home to tribal communities such as the Kondh, Bonda, and Santal, who have meticulously documented and preserved their knowledge of the local flora. These communities rely extensively on native plants for traditional cosmetic practices (Dash & Bhoi, 2024). For instance, turmeric (*Curcuma longa*) mixed with gram flour is used to prepare face packs for skin brightening and acne management. Neem (*Azadirachta indica*) and charcoal are utilized in tooth powders for oral hygiene due to their antibacterial properties (Kora 2024). Hibiscus (*Hibiscus rosa-sinensis*) and coconut oil are used to prepare nourishing hair oils, while sandalwood paste and rosewater are staples for skin care rituals. These phytocosmetic practices are deeply interwoven with the socio-cultural fabric of the tribes, reflecting their sustainable use of natural resources and their harmonious coexistence with the environment (Acharya *et al*., 2024).

Ethnobotanical surveys in the region have not only documented these traditional practices but have also revealed their scientific basis, offering potential applications in modern cosmetic formulations. With the global shift towards natural and organic cosmetics, the knowledge of tribal communities serves as an invaluable resource for developing innovative and sustainable products (Padhy *et al*. 2016). The active compounds in these plants can be isolated, characterized, and incorporated into advanced formulations for skin and hair care. For instance, the antibacterial and antifungal properties of neem make it a valuable ingredient for acne treatments and dandruff shampoos, while the antioxidant properties of turmeric can be utilized in anti-aging creams (Sahu & Sahu, 2017).

Future research in phytocosmetics can focus on the molecular mechanisms underlying the activity of plant-derived compounds, such as their interaction with cellular signaling pathways like mitogen-activated protein kinase (MAPK) and peroxisome proliferator-activated receptors (PPARs). These pathways play crucial roles in inflammation, cell proliferation, and lipid metabolism, making them key targets for cosmetic applications (Ahmed *et al*. 2022). Additionally, advancements in nanotechnology can enhance the bioavailability and stability of plant extracts, allowing for more effective delivery of active compounds to the skin and hair. For example, encapsulating flavonoids in liposomes or nanoparticles can improve their penetration into the dermal layers, maximizing their antioxidant and anti-inflammatory effects (Puglia *et al*. 2019). Integrating ethnobotanical knowledge with modern biotechnology also holds promise for the development of personalized phytocosmetic solutions. By analyzing individual skin and hair profiles, tailored formulations can be created to address specific needs, such as pigmentation disorders, dryness, or sensitivity. Moreover, sustainable practices such as green extraction techniques and biodegradable packaging can further align phytocosmetics with the principles of environmental conservation (Segueni *et al*. 2022).

The primary objective of this research was to conduct an ethnobotanical survey in the western Odisha region to document and analyze the traditional knowledge and practices of tribal communities related to the use of local plants in phytocosmetics. The study aims to identify, and evaluate plant species utilized for cosmetic purposes, understand their methods of preparation and application, and explore their cultural and pharmacological significance. Additionally, the research seeks to bridge traditional knowledge with modern scientific approaches to develop sustainable, eco-friendly cosmetic solutions and promote the preservation of indigenous practices.

## Materials and Methods

### Study area

Western Odisha, comprising the districts of Kalahandi, Balangir, Sambalpur, Jharsuguda, Sundargarh, and Bargarh, is a culturally rich and geographically diverse region characterized by plains, plateaus, hills, and river valleys. It forms part of the Eastern Ghats, with prominent highlands like the Gandhamardan Hills and Niyamgiri Hills, both of which have significant ecological and cultural importance (Pany *et al*. 2016). The fertile plains of the Mahanadi River, along with its tributaries such as the Tel and Ib rivers, play a vital role in the region's agriculture and socio-economic structure, supporting crops like paddy, millets, and oilseeds, along with forest-based resources like bamboo and medicinal herbs (Acharya *et al*. 2023).

The climate in Western Odisha is a blend of tropical and subtropical conditions, influenced by its varied terrain, and its deciduous forests are home to a wealth of plant and animal species, many of which are endemic to the region. The forests provide essential resources for the tribal communities, such as the Kondh, Bonda, and Santal, who have developed intricate knowledge systems to utilize local plants for medicinal and cosmetic purposes (Swain 2014). The abundant availability of plants like turmeric, neem, hibiscus, and sandalwood in these forests and agricultural lands has led to their extensive use in traditional phytocosmetics. The diverse geographical features and rich biodiversity of Western Odisha highlight its significance as both an ecological hotspot and a repository of traditional knowledge, especially in the sustainable use of plants for health and beauty practices (Munda *et al*. 2023). Fig. 1 depicts the map of the study area.

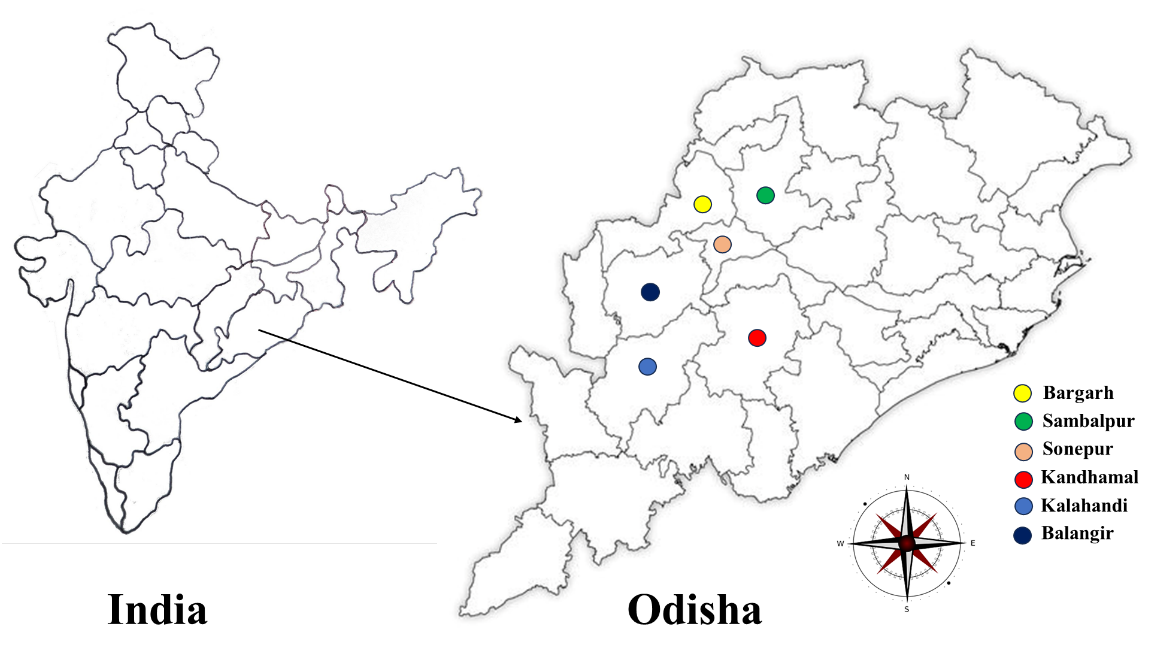


Figure 1. Map of the study area

**Ethnobotanical data collection**

The ethnobotanical survey was conducted in the tribal-dominated regions of Western Odisha, covering the districts of Kalahandi, Balangir, Sambalpur, Jharsuguda, Sundargarh, and Bargarh. These areas were selected for their rich biodiversity and the presence of tribal communities such as the Kondh, Bonda, and Santal, who are known for their extensive knowledge and use of plant-based products. The study focused on documenting traditional knowledge regarding the use of plants for phytocosmetics. Semi-structured interviews were conducted with key informants, including tribal elders, traditional healers, and women who are primary users of phytocosmetics, to gather information about local plant names, parts used, preparation methods, and applications. Focus group discussions were held to verify individual responses and capture collective knowledge about the cultural and social significance of phytocosmetics. Field observations included visits to forests, agricultural lands, and local markets to observe plant collection, preparation, and usage practices (Vandebroek & Albuquerque, 2024).

The plant specimens mentioned in the survey were collected and identified with the assistance of taxonomists, with all samples preserved in a herbarium for future reference. A total of 10 field visits were conducted to ensure comprehensive data collection between September 2024 to December 2024. Purposive and snowball sampling methods were used to identify knowledgeable participants, resulting in interviews with 112 informants, comprising both men and women aged between 25 and 80 years. During these visits, data were carefully recorded in field notebooks and later transcribed, documenting crucial details such as local plant names, families, parts used, preparation methods, applications, and seasonal availability. In addition, digital photographs of plants and their various uses were captured to provide visual support for the documentation. Ethical considerations were rigorously followed by obtaining prior informed consent from all participants and explaining the study's objectives in the local languages to ensure transparency. The scientific names, classifications, and taxonomic details of the plant species mentioned in this study were carefully verified using the Plants of the World Online (POWO) database (https://powo.science.kew.org) to ensure accuracy and consistency in nomenclature. The findings were subsequently shared with the local communities as an acknowledgment and a mark of respect for their invaluable contributions to the research. Fig. 2 represents a pictorial representation of an ethnobotanical survey conducted in the study region.


Figure 2. Pictorial representation of an ethnobotanical survey conducted in a specific area**:** [A] Collection of plant specimens of the sample *Curcuma longa* for the herbarium. [B] Visit a specific area where *Withania somnifera (L.) Dunal* and *Glycyrrhiza glabra L.* were harvested at the study location. [C] Collection of data from informants in the study area. [D] A field visit to the garden where *Allium cepa L.* and *Allium sativum L.* were harvested.

**Data analysis**

We evaluated the gathered ethnobotanical data employing diverse quantitative metrics to determine the significance and cultural relevance of plant species used in phytocosmetics. The calculation of informant participation (IP) and informant response (IR) was conducted using the following formula.

IP = ∑ (Total participants providing information on a specific plant)
IP = ∑ (Total responses for a specific plant)

We utilized the Use Value (UV) index to assess the relative significance of each plant species according to the frequency of uses documented by the informants (Leonti 2022). We computed the UV as

$$UV = \frac{\sum U}{N}$$

where ∑U signifies the aggregate number of uses referenced for a species, and NN indicates the count of informants. This enabled us to recognize plants with considerable variety and importance in traditional practices. We recorded the Use Report (UR) as the aggregate number of occurrences in which informants referenced a particular plant species for any application. This enabled us to ascertain the prominence of specific plants throughout the community.

UR = ∑ (Total number of uses cited for a specific plant)

Furthermore, we computed the Relative Frequency of Citation (RFC) to assess the agreement among informants concerning the utilization of specific plant species (Leonti 2022). We utilized the RFC formula.

$$RFC = \frac{FC}{N}$$

where FC denotes the count of informants who identified a species, and N represents the total number of informants. This allowed us to assess the extensive acknowledgment and cultural significance of each plant. We employed the Cultural Importance Index (CI) to assess the overall relevance of plant species, considering the diversity of their applications across multiple domains. This method enabled us to understand the significant role specific plants played in the community's cultural activities (Leonti 2022). The confidence interval can be computed as follows:

$$CI = \sum_{j=1}^{n} \left( \mathrm{n} \frac{URij}{N} \right)$$

Additionally, we computed the fidelity level (FL) to evaluate the uniqueness of plant utilization for specified applications (Janaćković et al. 2022). We utilized the formula.

$$FL\ (\%) = \frac{Np}{N} \times 100$$

where Np represents the quantity of informants referencing the plant for a particular application, and NN denotes the overall number of informants acknowledging the plant. This allowed us to pinpoint plants primarily utilized for particular phytocosmetic purposes.

## Results

**Demographic Information of the Participants**

The demographic data of the participants (N=112) provides some critical insights. The locality with the largest participant representation was Sonepur (20.53%), whereas Bargarh had the lowest (11.60%). Males comprised 55.35% of the participants, while females represented 44.64%. In terms of vocations, herbalists constituted the predominant group at 33.92% of the participants, whilst Ayurvedic practitioners comprised the lowest group at merely 11.60%. The predominant age group among participants was 60–80 years, comprising 36.60%, whilst the least represented group was those above 80 years, accounting for 14.28%. The educational levels indicated that most participants (59.82%) had attained primary education, while the smallest proportion (13.39%) had not received any formal education. This statistic emphasizes the most and least represented groups across diverse socio-demographic factors. Table 1 displays the demographic data of the participants.

Table 1. Demographical information of the participant

| Socio-Demographic Variables | Parameters | Sample number (N=112) | Percentage (%) |
|---|---|---|---|
| Locality | Kalahandi | 24 | 21.42 |
| | Kandhamal | 15 | 13.39 |
| | Balangir | 19 | 16.96 |
| | Sonepur | 23 | 20.53 |
| | Bargarh | 13 | 11.60 |
| | Sambalpur | 18 | 16.07 |
| Gender | Male | 62 | 55.35 |
| | Female | 50 | 44.64 |
| Occupation | Herbalist | 38 | 33.92 |
| | Traditional Healers (Vaidyas or Gurus) | 34 | 30.35 |
| | Tribal Elders | 27 | 24.10 |
| | Ayurvedic practitioner | 13 | 11.60 |
| Age | <40 | 20 | 17.85 |
| | 40-60 | 35 | 31.25 |
| | 60-80 | 41 | 36.60 |
| | >80 | 16 | 14.28 |
| Education | No study | 15 | 13.39 |
| | Primary | 67 | 59.82 |
| | High school | 17 | 15.17 |
| | University | 13 | 11.60 |
| N = Number of respondants | | | |

**Information regarding the tribal communities of the area and common phytocosmetics preparations**

Ethnobotanical research in Western Odisha uncovers a robust heritage of phytocosmetics within tribal tribes, highlighting sustainable and natural methodologies for skincare and personal grooming. The Herbal Face Pack (Ubtan), composed of turmeric, sandalwood powder, and gram flour, is extensively utilized by the Kutia, Kandha, and Bhulia tribes for enhancing skin luminosity and diminishing imperfections. The Natural Eyeliner (Surma), composed of castor oil and lamp soot, accentuates the eyes and alleviates discomfort, a tradition among the Gond, Bond, and Kandha tribes. Hair care practices encompass Hair Oil (Thengai Ennai Mix), flavored with curry leaves and hibiscus flowers, and Hair Conditioner (Methi Paste), composed of fenugreek seeds, yogurt, and honey. These procedures, common among the Bhulia, Kulta, Kandha, Sundhi, and Pana tribes, naturally fortify and nurture hair. The Santal, Kandha, and Harijan tribes utilize Herbal Tooth Powder (Daatun Choornam), composed of neem leaves, charcoal, and clove powder, for oral hygiene. The Soapnut Shampoo (Reetha Shikakai Wash) serves as a natural cleaner that inhibits dandruff, and the Skin Moisturizer (Kumari Lepan), composed of aloe vera, honey, and almond oil, provides hydration to the skin. Additional significant preparations encompass Natural Perfume (Gulab Jal) and Sunscreen (Surjyamukhi), exemplifying the tribes' ingenious utilization of natural biodiversity for cosmetic purposes. These approaches underscore the potential for sustainable, nature-inspired personal care solutions. Table 2 delineates prevalent traditional phytocosmetics primarily utilized in Western Odisha communities, accompanied by their preparation techniques.

Table 2. Common Traditional Phytocosmetics Mostly Used in Western Odisha Communities with Their Methods of Preparation

| Cosmetic Name | Traditional Name | Ingredients | Method of Preparation | Uses | Name of the tribal communities who prepared primarily |
|---|---|---|---|---|---|
| Herbal Face Pack | Ubtan | Turmeric, sandalwood powder, gram flour, milk | Combine turmeric, sandalwood powder, and gram flour. Incorporate milk or water to create a paste. Apply to the face, then rinse off. | Brightens skin and reduces blemishes | Kutia, Kandha, Bhulia |
| Kajal (Natural Eyeliner) | Surma | Castor oil, lamp soot | Utilize a tiny diya (light) to burn castor oil. Gather the soot onto a pristine metal plate. Combine with a small amount of ghee. | Enhances eyes, soothes irritation | Gond, Bond, Kandha |
| Lip Stain | Chukandar Ras | Beetroot juice, coconut oil | Obtain beetroot juice by grating and pressing the root. Combine with coconut oil and keep in a small receptacle. | Provides natural lip color | Bonda, Santal, Kutia |
| Hair Oil | Thengai Ennai Mix | Coconut oil, curry leaves, hibiscus flowers | Heat coconut oil with curry leaves and hibiscus flowers till the fragrance intensifies. Cool and filter into a bottle. | Strengthens hair, prevents hair fall | Bhulia, Kulta, Kandha |
| Soapnut Shampoo | Reetha Shikakai Wash | Soapnut (reetha), shikakai pods, water | Simmer soapnut and shikakai in water until a froth forms. Filter the liquid and utilize it as a natural shampoo. | Cleans hair, prevents dandruff | Khandayat, Brahmin, Bonda |
| Herbal Tooth Powder | Daatun Choornam | Neem leaves, charcoal, salt, clove powder | Dehydrate neem leaves and pulverize them with charcoal, salt, and clove powder to create a fine powder. Preserve in a container. | Whitens teeth, maintains oral health | Santal, Kandha, Harijan |

| | | | | | |
|---|---|---|---|---|---|
| Body Scrub | Aattan | Rice flour, mustard oil, sugar | Combine rice flour and sugar with mustard oil to produce a coarse exfoliant. Utilize during bathing. | Exfoliates skin, improves blood flow | Gond, Saura, Teli, Mali |
| Natural Perfume | Gulab Jal | Rose petals, water, sandalwood oil | Infuse rose petals in water to produce rose water. Incorporate several droplets of sandalwood oil for scent. | Provides a refreshing fragrance | Harijan, Mali, Kulta |
| Hair Dye | Mehendi Paste | Henna leaves, tea decoction, lemon juice | Crush fresh henna leaves into a paste. Incorporate tea infusion and lemon juice. Apply to hair and allow to remain for 2–3 hours. | Colors hair naturally, conditions hair | Khandayat, Brahmin, Pujhari |
| Skin Moisturizer | Kumari Lepan | Aloe vera gel, honey, almond oil | Obtain aloe vera gel. Combine honey and almond oil to create a silky moisturizing cream. | Hydrates and soothes skin | Bhulia, Gond, Santal |
| Foot Scrub | Paad Safai | Crushed walnut shells, neem oil, turmeric | Crush walnut shells and combine with neem oil and turmeric. Gently exfoliate the feet. | Removes dead skin, soothes cracks | Teli, Sundhi, Gond |
| Hair Conditioner | Methi Paste | Fenugreek seeds, yogurt, honey | Immerse fenugreek seeds in water overnight. Crush into a paste and combine with yogurt and honey. Apply to hair for thirty minutes. | Smoothens and nourishes hair | Kandha, Sundhi, Pana |
| Sunscreen | Surjyamukhi | Sesame oil, turmeric, rice paste | Combine sesame oil with turmeric powder and rice paste. Apply sparingly on exposed skin. | Protects skin from UV rays | Pujhari, Teli, Mali, Kansari |
| Hand Cream | Malai Lepan | Milk cream, glycerin, rose water | Combine milk cream with glycerin and rose water. Apply to hands and allow to absorb overnight. | Softens and hydrates hands | Kutia, Gond, Santali |

| | | | | | |
|---|---|---|---|---|---|
| Eye Soother | Kakdi Pad | Cucumber slices, rose water | Immerse cucumber slices in rose water. Apply on the eyes for a duration of 15 minutes. | Reduces puffiness, cools eyes | Koya, Mundari, Bhukta |

**Information regarding the reported plant species and their utility**

The ethnobotanical survey emphasizes significant species utilized as phytocosmetics by people in Western Odisha. A total of 39 plant species were gathered from 33 distinct families. Figure 3 depicts the distribution of 33 plant families discovered in the ethnobotanical survey.

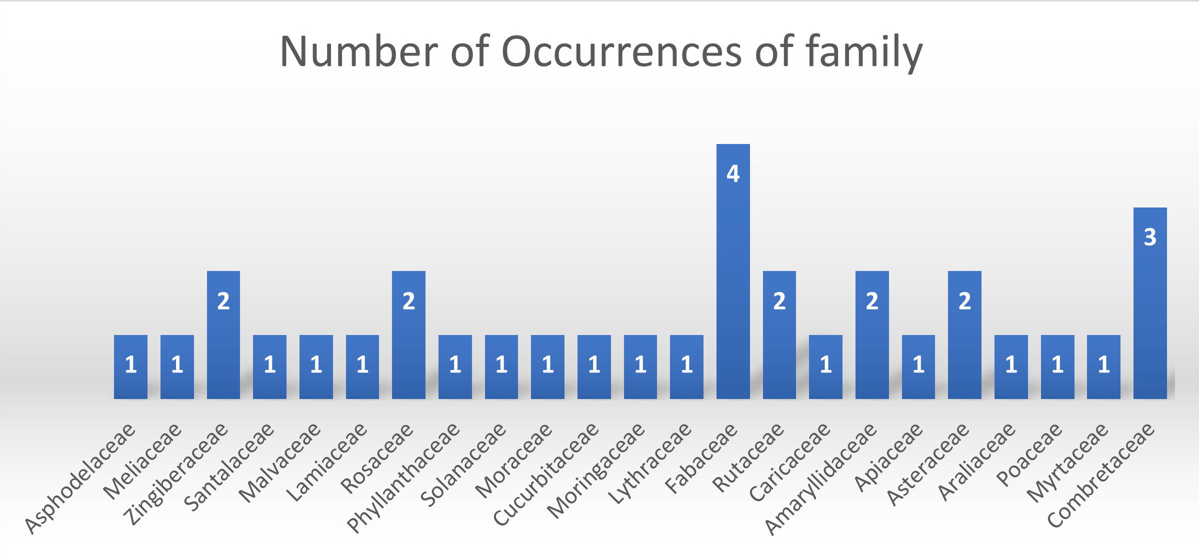


Figure 3. Distribution of distinct families amongst plant specimens from the ethnobotanical survey

Aloe vera (Kumari), accessible throughout the year, is extensively utilized for its gel in skin moisturizers and calming formulations. Leaves and oil of Neem (*Azadirachta indica*), collected from March to May, are integral to traditional tooth powders and skincare products due to its antibacterial characteristics. Turmeric (*Curcuma longa*), harvested for its rhizomes from November to February, is a prevalent component in herbal face masks and sunscreens owing to its brightening and anti-inflammatory properties. Hibiscus (*Hibiscus rosa-sinensis*), esteemed for its blossoms and foliage, is utilized in hair oils and shampoos to enhance hair vitality. The leaves of Tulsi (*Ocimum sanctum*) are utilized as a foundation for calming ocular remedies and invigorating facial tonics. Petals and oil from Indian Rose (*Rosa indica*), collected from November to March, are essential components in natural perfumes and lip stains. Rare plants like Vetiver (*Chrysopogon zizanioides*) and Gotu Kola (*Centella asiatica*) are esteemed for their roots and leaves in foot washes and anti-aging products. Henna (*Lawsonia inermis*), harvested for its foliage, is widely utilized as a natural hair color and conditioner. Table 3 enumerates the plants utilized as phytocosmetics, accompanied by their fundamental botanical information.

*Aloe barbadensis* (Aloe vera) is frequently utilized in phytocosmetics, wherein fresh gel derived from the leaves is combined with components such as rose water and lemon juice to create a calming gel. This formulation is extensively utilized for hydration and acne therapy due to its moisturizing and anti-inflammatory attributes. *Azadirachta indica* (Neem) is a significant component, with leaves being boiled and processed into a paste, frequently amalgamated with turmeric and yogurt. This neem paste is renowned for its antibacterial characteristics, rendering it suitable for facial and scalp applications to address skin problems and foster healthy hair. *Curcuma longa* (turmeric) is processed by drying and grinding the rhizomes, which are subsequently combined with milk and honey to create a paste utilized as a facial mask. Its anti-inflammatory and antioxidant characteristics facilitate skin regeneration. *Santalum album* (Sandalwood) is processed by grinding the wood into a paste with water, frequently combined with rose water or turmeric. This paste is utilized as a dermal mask to alleviate and enhance skin texture.

Table 3. List of Plants Used as Phytocosmetics with Their Basic Botanical Details

| Family | Scientific Name | Common Name | Vernacular Name | Voucher Specimen Number | Part Used | Season Harvested | Growth Status | Plant habitus | Present status | Collection Methods |
|---|---|---|---|---|---|---|---|---|---|---|
| Asphodelaceae | *Aloe barbadensis* Mill. | Aloe Vera | Kumari | CUTM/BOT/1132 | Leaf gel | Year-round | C | H | A | Cutting |
| Meliaceae | *Azadirachta indica* A. Juss. | Neem | Nimba | CUTM/BOT/1106 | Leaves, oil | March-May | W | T | A | Harvesting leaves |
| Zingiberaceae | *Curcuma longa* L. | Turmeric | Haladi | CUTM/BOT/1110 | Rhizome | November-February | C | H | A | Plucking leaves |
| Santalaceae | *Santalum album* L. | Sandalwood | Chandana | CUTM/BOT/1118 | Wood, oil | Year-round | C | T | R | Harvesting rhizomes |
| Malvaceae | *Hibiscus rosa-sinensis* L. | Hibiscus | Mandara | CUTM/BOT/1120 | Flowers, leaves | Year-round | W | T | A | Cutting wood |
| Lamiaceae | *Ocimum sanctum* L. | Tulsi (Holy Basil) | Tulasi | CUTM/BOT/1125 | Leaves | Year-round | W | S | A | Plucking flowers |
| Rosaceae | *Rosa indica* L. | Indian Rose | Golapa | CUTM/BOT/1129 | Petals, oil | November-March | C | T | A | Plucking leaves |
| Phyllanthaceae | *Phyllanthus emblica* L. | Indian Gooseberry | Amla | CUTM/BOT/1134 | Fruit | October-February | W | T | A | Plucking flowers |
| Solanaceae | *Withania somnifera* (L.) Dunal | Ashwagandha | Ashwagandha | CUTM/BOT/1109 | Root | December-March | C | S | R | Picking fruits |
| Moraceae | *Ficus benghalensis* L. | Banyan | Bara | CUTM/BOT/1111 | Bark, leaves | Year-round | W | T | A | Harvesting roots |
| Cucurbitaceae | *Momordica charantia* L. | Bitter Gourd | Karala | CUTM/BOT/1128 | Fruit | June-September | W | Cl. | A | Collecting bark or leaves |
| Moringaceae | *Moringa oleifera* Lam. | Moringa | Sajana | CUTM/BOT/1113 | Leaves, seeds | February-April | W | T | A | Picking fruits |
| Lythraceae | *Lawsonia inermis* L. | Henna | Mehendi | CUTM/BOT/1140 | Leaves | April-June | W | T | R | Picking leaves or pods |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Fabaceae | *Acacia concinna* (Willd.) DC. | Shikakai | Shikakai | CUTM/BOT/1102 | Pods, leaves | October-March | W | T | R | Plucking leaves |
| Rutaceae | *Aegle marmelos* (L.) Corrêa | Bael | Bela | CUTM/BOT/1143 | Fruit, leaves | April-June | W | T | A | Collecting pods |
| Fabaceae | *Glycyrrhiza glabra* L. | Licorice | Yashtimadhu | CUTM/BOT/1124 | Root | November-February | C | H | R | Picking fruits |
| Caricaceae | *Carica papaya* L. | Papaya | Amruta Bhanda | CUTM/BOT/1114 | Fruit | Year-round | W | T | A | Harvesting roots |
| Rosaceae | *Prunus amygdalus* Batsch | Bitter Almond | Badam | CUTM/BOT/1105 | Seeds | January-March | W | T | A | Picking fruits |
| Amaryllidaceae | *Allium cepa* L. | Onion | Piaja | CUTM/BOT/1132 | Bulb | November-February | C | S | A | Picking seeds |
| Amaryllidaceae | *Allium sativum* L. | Garlic | Rasuna | CUTM/BOT/1132 | Bulb | November-March | C | S | A | Harvesting bulbs |
| Apiaceae | *Centella asiatica* (L.) Urb. | Gotu Kola | Brahmi | CUTM/BOT/1132 | Leaves, extract | Year-round | W | Cl. | R | Harvesting bulbs |
| Asteraceae | *Tagetes erecta* L. | Marigold | Genda | CUTM/BOT/1132 | Flowers | October-February | W | H | A | Plucking leaves |
| Araliaceae | *Hydrocotyle asiatica* L. | Indian Pennywort | Thankuni | CUTM/BOT/1132 | Leaves | Year-round | W | Cl. | R | Plucking flowers |
| Asteraceae | *Eclipta prostrata* (L.) L. | Bhringraj | Kesuti | CUTM/BOT/1132 | Leaves, oil | August-November | C | H | R | Plucking leaves |
| Poaceae | *Chrysopogon zizanioides* (L.) Roberty | Vetiver | Khas | CUTM/BOT/1132 | Roots | January-March | W | H | R | Plucking leaves |
| Rutaceae | *Murraya koenigii* (L.) Spreng. | Curry Leaves | Bhursunga | CUTM/BOT/1132 | Leaves | Year-round | W | T | A | Harvesting roots |
| Myrtaceae | *Syzygium cumini* (L.) Skeels | Jamun | Jamukoli | CUTM/BOT/1132 | Seeds, bark | June-August | W | T | A | Plucking leaves |
| Combretaceae | *Terminalia bellirica* (Gaertn.) Roxb. | Baheda | Bahada | CUTM/BOT/1132 | Fruit | November-February | W | T | A | Picking fruits |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Combretaceae | *Terminalia chebula* Retz. | Haritaki | Harida | CUTM/BOT/1132 | Fruit | October-February | W | T | A | Picking fruits |
| Combretaceae | *Terminalia arjuna* (Roxb. ex DC.) Wight & Arn. | Arjuna | Arjuna | CUTM/BOT/1132 | Bark | March-May | W | T | R | Picking fruits |
| Rubiaceae | *Rubia cordifolia* L. | Indian Madder | Manjistha | CUTM/BOT/1132 | Roots | October-February | W | H | R | Collecting bark |
| Apocynaceae | *Hemidesmus indicus* (L.) R. Br. ex Schult. | Indian Sarsaparilla | Sugandhi | CUTM/BOT/1132 | Roots | November-March | W | H | R | Harvesting roots |
| Rubiaceae | *Rubia tinctorum* L. | Manjistha | Manjistha | CUTM/BOT/1132 | Roots, stem | Year-round | W | H | R | Harvesting roots |
| Fabaceae | *Butea monosperma* (Lam.) Taub. | Flame of the Forest | Palasha | CUTM/BOT/1132 | Flowers | February-April | W | T | A | Harvesting roots |
| Arecaceae | *Cocos nucifera* L. | Coconut Palm | Nariyal | CUTM/BOT/1132 | Oil, milk | Year-round | W | T | A | Plucking flowers |
| Sapindaceae | *Sapindus mukorossi* Gaertn. | Soapnut (Reetha) | Ritha | CUTM/BOT/1132 | Fruit | June-September | W | T | A | Picking fruits (coconuts) |
| Fabaceae | *Pongamia pinnata* (L.) Pierre | Indian Beech | Karanja | CUTM/BOT/1132 | Seeds, oil | Year-round | W | T | A | Collecting pods |
| Acoraceae | *Acorus calamus* L. | Sweet Flag | Bach | CUTM/BOT/1132 | Rhizome | December-March | C | H | R | Collecting seeds or pods |
| Zingiberaceae | *Curcuma aromatica* Salisb. | Wild Turmeric | Ban Haladi | CUTM/BOT/1132 | Fruit, seeds | May-August | C | H | R | Harvesting rhizomes |

W = Wild; C = Cultivated; H = Herbaceous; T = Tree; S = Shrub; Cl. = Climber; A = Abundant; R = Rare

Hibiscus rosa-sinensis is pulverized into a paste, usually mixed with coconut oil or fenugreek powder, and applied to the skin and hair for its anti-aging and conditioning properties. The leaves of *Ocimum sanctum* (Tulsi) are either pulverized or extracted and combined with honey and lemon juice to produce a juice or paste. This composition aids in combating acne and fostering healthy skin. Likewise, *Rosa indica* (Indian Rose) petals are pulverized and either transformed into a paste or steeped in water, frequently mixed with milk or sandalwood powder, resulting in a calming toner or face mask that enhances skin luminosity. Table 4 delineates the prevalent preparation methods for several cosmetics derived from plants, along by their characteristic chemical elements.

Table 4. Common Methods of Preparation for Different Cosmetics Using Plants and Their Common Chemical Constituents

| Common Name | Method of Preparation | Mode of Application | Other Additional Ingredients | Obtained formulation |
|---|---|---|---|---|
| *Aloe barbadensis* Mill. | Fresh leaves are harvested and the gel is extracted manually for use. | Applied directly to skin or hair. | Rose water, lemon juice | Gel |
| *Azadirachta indica* A. Juss. | Leaves are boiled, then ground into a smooth paste. | Applied to face or scalp. | Turmeric, yogurt | Paste |
| *Curcuma longa* L. | Rhizomes are dried, powdered, and blended with milk to form a uniform mixture. | Used as a face pack. | Honey, sandalwood powder | Paste |
| *Santalum album* L. | Wood is finely ground and mixed with water to prepare a paste. | Applied as a skin mask. | Rose water, turmeric | Paste |
| *Hibiscus rosa-sinensis* L. | Flowers are crushed thoroughly to obtain a fine paste. | Applied to hair or skin. | Coconut oil, fenugreek powder | Paste |
| *Ocimum sanctum* L. | Leaves are either crushed or juiced to extract their active components. | Applied to skin or scalp. | Honey, lemon juice | Juice/Paste |
| *Rosa indica* L. | Petals are crushed into a paste or infused in water for further use. | Used as a toner or face mask. | Milk, sandalwood powder | Paste/Infusion |
| *Phyllanthus emblica* L. | Fruits are dried, powdered, and combined with water to create a paste. | Applied to scalp or face. | Shikakai, reetha | Powder/Paste |
| *Withania somnifera* (L.) Dunal | Roots are dried, powdered, and mixed with either water or milk. | Used as a skin mask. | Honey, yogurt | Paste |
| *Ficus benghalensis* L. | Aerial roots are soaked and then ground into a paste-like consistency. | Applied to scalp. | Coconut oil, hibiscus | Paste |
| *Momordica charantia* L. | Fruits are juiced or crushed into a paste depending on the formulation. | Used as a face pack. | Turmeric, yogurt | Paste/Juice |

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|---|---|---|---|---|
| *Moringa oleifera* Lam. | Leaves are powdered and reconstituted with water before application. | Applied to scalp or face. | Aloe vera, coconut oil | Powder/Paste |
| *Lawsonia inermis* L. | Dried leaves are ground into powder and mixed with water to form a paste. | Applied to hair or skin. | Tea decoction, lemon juice | Paste |
| *Acacia concinna* (Willd.) DC. | Pods are dried, powdered, and decocted by boiling in water. | Used as a hair cleanser. | Reetha, hibiscus | Decoction |
| *Aegle marmelos* (L.) Corrêa | Fruit pulp is blended with honey or milk to make a nourishing paste. | Applied to face. | Rose water, sandalwood powder | Paste |
| *Glycyrrhiza glabra* L. | Roots are dried, powdered, and combined with milk to form a paste. | Used as a face mask. | Honey, turmeric | Paste |
| *Carica papaya* L. | Ripe fruit is mashed into a paste for topical use. | Applied to face or hair. | Honey, lemon juice | Paste |
| *Prunus amygdalus* Batsch | Seeds are ground with milk to form a smooth, creamy paste. | Applied to skin or hair. | Milk, rose water | Paste |
| *Allium cepa* L. | Bulbs are juiced and mixed with a carrier oil for application. | Massaged onto scalp. | Coconut oil, castor oil | Oil-infused Juice |
| *Allium sativum* L. | Cloves are crushed and combined with honey to form a therapeutic paste. | Applied to scalp or skin. | Honey, lemon juice | Paste |
| *Centella asiatica* (L.) Urb. | Leaves are either crushed or powdered for preparation. | Applied to skin. | Aloe vera, rose water | Juice/Powder |
| *Tagetes erecta* L. | Flowers are crushed to obtain a paste rich in bioactive compounds. | Applied to skin. | Turmeric, yogurt | Paste |
| *Hydrocotyle asiatica* L. | Leaves are juiced or powdered to retain their natural constituents. | Applied as a face pack. | Honey, aloe vera gel | Juice/Powder |
| *Eclipta prostrata* (L.) L. | Leaves are juiced and blended with coconut oil to enhance application. | Massaged onto scalp. | Amla oil, hibiscus | Oil-infused Juice |
| *Chrysopogon zizanioides* (L.) Roberty | Roots are soaked and ground to create a cooling, aromatic paste. | Used as a cooling mask. | Rose water, sandalwood powder | Paste |

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|---|---|---|---|---|
| *Murraya koenigii* (L.) Spreng. | Leaves are ground and mixed with yogurt to form a conditioning agent. | Applied to hair or skin. | Coconut oil, hibiscus | Paste |
| *Syzygium cumini* (L.) Skeels | Seeds are powdered and blended with honey for topical use. | Applied to face. | Lemon juice, yogurt | Paste |
| *Terminalia bellirica* (Gaertn.) Roxb. | Fruits are powdered and mixed with water to create a uniform paste. | Applied as a face pack. | Turmeric, honey | Paste |
| *Terminalia chebula* Retz. | Fruits are powdered and blended with yogurt for hair or skin care. | Used as a hair or face pack. | Amla, reetha | Paste |
| *Terminalia arjuna* (Roxb. ex DC.) Wight & Arn. | Bark is powdered and combined with milk or water to make a healing mask. | Applied to skin. | Honey, rose water | Paste |
| *Rubia cordifolia* L. | Roots are powdered and mixed with rose water for a soothing application. | Used as a skin mask. | Turmeric, sandalwood | Paste |
| *Hemidesmus indicus* (L.) R. Br. ex Schult. | Roots are boiled to prepare a decoction with medicinal properties. | Applied to skin. | Honey, milk | Decoction |
| *Rubia tinctorum* L. | Roots are crushed and blended with yogurt for rejuvenating effects. | Applied to skin. | Turmeric, aloe vera | Paste |
| *Butea monosperma* (Lam.) Taub. | Flowers are boiled to extract a paste used for skin and hair treatments. | Used for hair or skin. | Coconut oil, hibiscus | Paste |
| *Cocos nucifera* L. | Oil is obtained through cold pressing of the dried kernel. | Applied to scalp or skin. | Curry leaf, fenugreek | Oil |
| *Sapindus mukorossi* Gaertn. | Pods are soaked and boiled in water to yield a cleansing solution. | Used as a hair cleanser. | Shikakai, hibiscus | Decoction |
| *Pongamia pinnata* (L.) Pierre | Seeds are pressed to extract a therapeutic oil. | Applied to skin. | Turmeric, aloe vera gel | Oil |
| *Acorus calamus* L. | Rhizomes are dried, powdered, and mixed with water into a smooth paste. | Used as a face pack. | Rose water, sandalwood | Paste |
| *Curcuma aromatica* Salisb. | The rhizome is powdered and blended with milk to create a skin mask. | Applied as a skin mask. | Chickpea flour, honey | Paste |

**Calculations of distinct quantitative parameters for determining the distribution of plant species**

The quantitative metrics indicated that, for Informant Participant (IP), the highest values are observed in *Santalum album* (110), *Lawsonia inermis* (110), and *Acacia concinna* (108). Regarding Informant Response (IR), *Santalum album* ranks first with 109, closely followed by *Lawsonia inermis* (109) and *Acacia concinna* (106). In the Use Report (UR), *Santalum album* ranks first with a score of 105, followed closely by *Lawsonia inermis* at 106 and *Acacia concinna* at 104. In terms of Use Value (UV), *Santalum album* is rated at 0.93, followed by *Curcuma aromatica* at 0.90 and *Chrysopogon zizanioides* at 0.89. Regarding Relative Frequency Citation (RFC), *Santalum album* possesses the greatest value of 0.98, succeeded by *Lawsonia inermis* at 0.97 and *Curcuma aromatica* at 0.94. Ultimately, *Santalum album* ranks highest on the Cultural Index (CI) with a score of 0.97, succeeded by *Lawsonia inermis* at 0.98 and *Curcuma aromatica* at 0.93. Table 5 enumerates the quantitative parameter measurements, and the results derived from the study participants. Numerous plant species exhibit the highest pharmacological activity levels. Figure 4 illustrates the graphical representation of plant species with an RFC and CI value beyond 0.9. Figure 5 presents a series of pictures of plant species exhibiting RFC and CI values greater than 0.90.

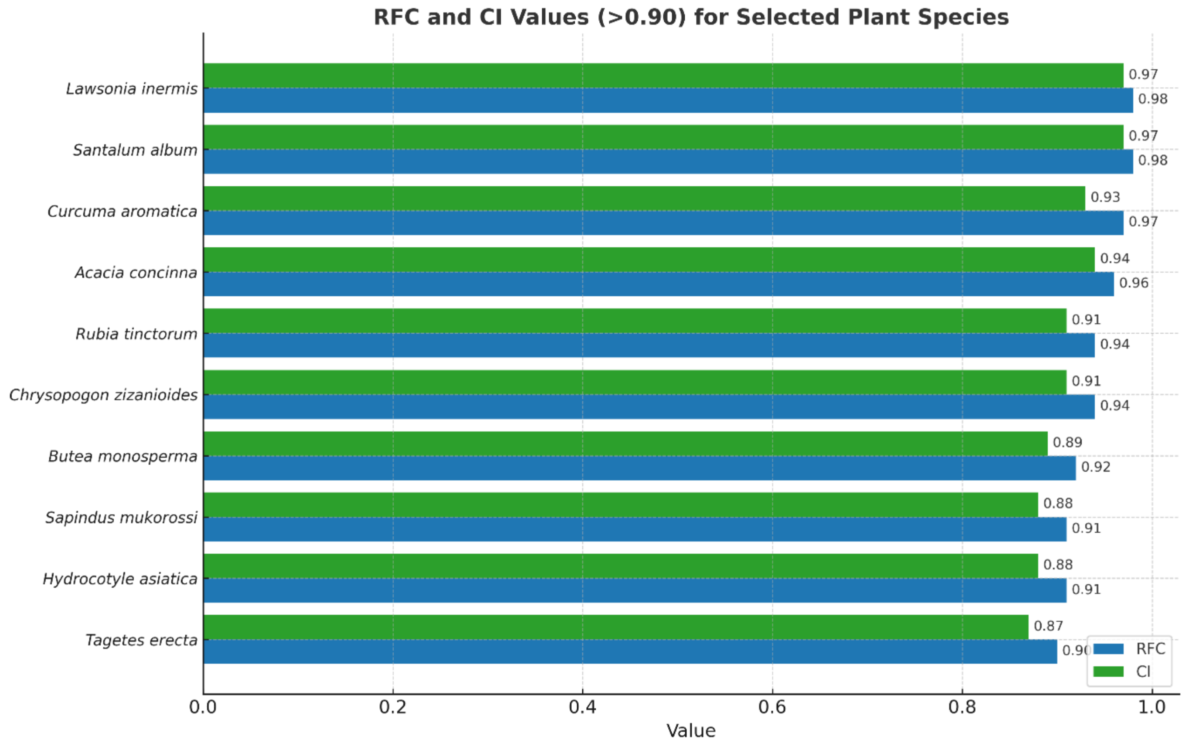


Figure 4. Representation of plant species above 0.9 RFC & CI

Table 5. Quantitative Parameter Measurements and Results Obtained from the Study Participants

| **Scientific Name** | **Number of informant participants (IP) per plant** | **Informant response (IR)** | **Use report (UR)** | **Use value (UV)** | **Relative frequency citation (RFC)** | **Cultural Index (CI)** |
|---|---|---|---|---|---|---|
| *Aloe barbadensis* Mill. | 92 | 90 | 88 | 0.78 | 0.82 | 0.80 |
| *Azadirachta indica* A. Juss. | 95 | 91 | 85 | 0.75 | 0.84 | 0.81 |
| *Curcuma longa* L. | 93 | 84 | 79 | 0.70 | 0.83 | 0.75 |
| *Santalum album* L. | 110 | 109 | 105 | 0.93 | 0.98 | 0.97 |
| *Hibiscus rosa-sinensis* L. | 100 | 98 | 92 | 0.75 | 0.89 | 0.87 |
| *Ocimum sanctum* L. | 82 | 80 | 75 | 0.66 | 0.73 | 0.71 |
| *Rosa indica* L. | 89 | 84 | 80 | 0.71 | 0.79 | 0.75 |

| | | | | | | |
|---|---|---|---|---|---|---|
| *Phyllanthus emblica* L. | 92 | 91 | 84 | 0.75 | 0.82 | 0.81 |
| *Withania somnifera* (L.) Dunal | 96 | 92 | 89 | 0.79 | 0.85 | 0.82 |
| *Ficus benghalensis* L. | 84 | 81 | 78 | 0.69 | 0.75 | 0.72 |
| *Momordica charantia* L. | 99 | 95 | 86 | 0.76 | 0.88 | 0.84 |
| *Moringa oleifera* Lam. | 80 | 79 | 74 | 0.66 | 0.71 | 0.70 |
| *Lawsonia inermis* L. | 110 | 109 | 106 | 0.94 | 0.98 | 0.97 |
| *Acacia concinna* (Willd.) DC. | 108 | 106 | 104 | 0.92 | 0.96 | 0.94 |
| *Aegle marmelos* (L.) Corrêa | 95 | 90 | 85 | 0.75 | 0.84 | 0.80 |
| *Glycyrrhiza glabra* L. | 99 | 88 | 82 | 0.73 | 0.88 | 0.78 |
| *Carica papaya* L. | 89 | 85 | 82 | 0.73 | 0.79 | 0.75 |
| *Prunus amygdalus* Batsch | 84 | 82 | 80 | 0.71 | 0.75 | 0.73 |
| *Allium cepa* L. | 90 | 86 | 84 | 0.75 | 0.80 | 0.76 |
| *Allium sativum* L. | 86 | 84 | 81 | 0.72 | 0.76 | 0.75 |
| *Centella asiatica* (L.) Urb. | 81 | 78 | 74 | 0.66 | 0.72 | 0.69 |
| *Tagetes erecta* L. | 101 | 98 | 94 | 0.83 | 0.90 | 0.87 |
| *Hydrocotyle asiatica* L. | 103 | 99 | 95 | 0.84 | 0.91 | 0.88 |
| *Eclipta prostrata* (L.) L. | 95 | 94 | 90 | 0.80 | 0.84 | 0.83 |
| *Chrysopogon zizanioides* (L.) Roberty | 106 | 103 | 100 | 0.89 | 0.94 | 0.91 |
| *Murraya koenigii* (L.) Spreng. | 95 | 90 | 85 | 0.75 | 0.84 | 0.80 |
| *Syzygium cumini* (L.) Skeels | 97 | 94 | 92 | 0.82 | 0.81 | 0.83 |
| *Terminalia bellirica* (Gaertn.) Roxb. | 85 | 80 | 74 | 0.66 | 0.75 | 0.71 |
| *Terminalia chebula* Retz. | 84 | 82 | 79 | 0.70 | 0.75 | 0.73 |
| *Terminalia arjuna* (Roxb. ex DC.) Wight & Arn. | 94 | 92 | 90 | 0.80 | 0.83 | 0.82 |
| *Rubia cordifolia* L. | 91 | 88 | 87 | 0.77 | 0.81 | 0.78 |
| *Hemidesmus indicus* (L.) R. Br. ex Schult. | 89 | 85 | 85 | 0.75 | 0.79 | 0.75 |
| *Rubia tinctorum* L. | 106 | 102 | 100 | 0.89 | 0.94 | 0.91 |
| *Butea monosperma* (Lam.) Taub. | 104 | 100 | 97 | 0.86 | 0.92 | 0.89 |

| | | | | | | |
|---|---|---|---|---|---|---|
| *Cocos nucifera* L. | 95 | 91 | 89 | 0.79 | 0.84 | 0.81 |
| *Sapindus mukorossi* Gaertn. | 102 | 99 | 98 | 0.87 | 0.91 | 0.88 |
| *Pongamia pinnata* (L.) Pierre | 97 | 95 | 90 | 0.80 | 0.86 | 0.84 |
| *Acorus calamus* L. | 95 | 90 | 88 | 0.78 | 0.84 | 0.80 |
| *Curcuma aromatica* Salisb. | 109 | 105 | 101 | 0.90 | 0.97 | 0.93 |

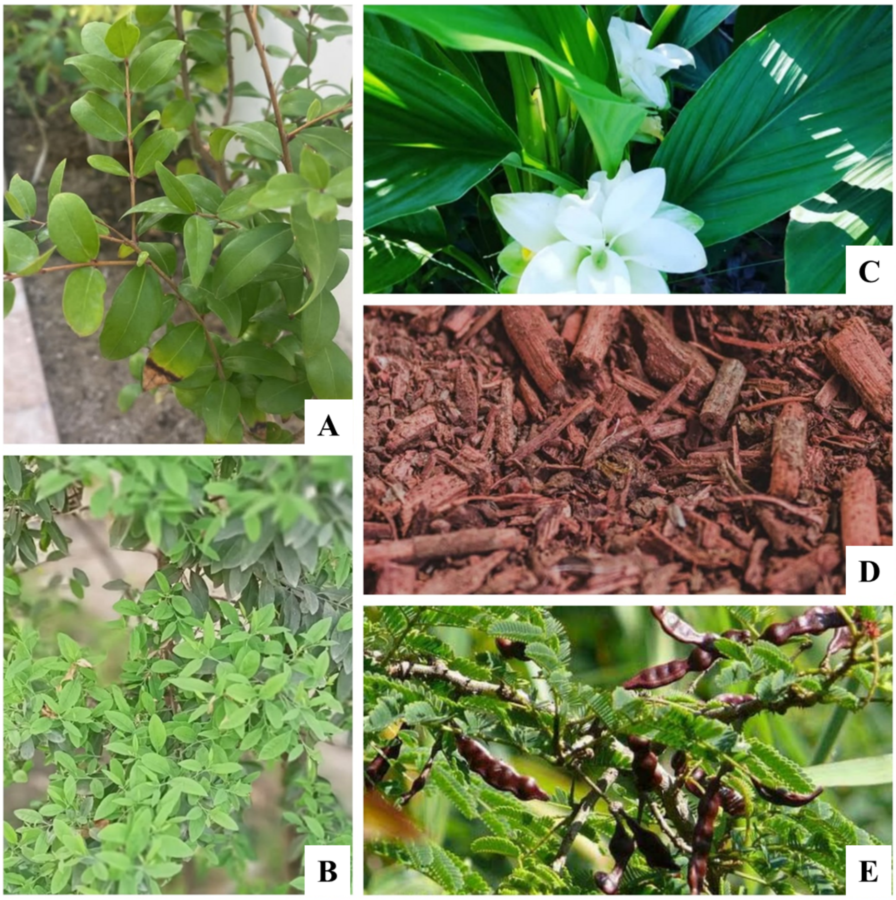


Figure 5. Collection of photographs of plant specimens whose RFC and CI are more than 0.90. [A] *Lawsonia inermis* L. (Henna), [B] *Santalum album* L. (Sandalwood), [C]*Curcuma aromatica* Salisb. [D]*Rubia tinctorum* L. (Manjistha), [E]*Acacia concinna* (Willd.) DC.

In the context of FL, *Santalum album* exhibits the highest anti-inflammatory capabilities at 97%, followed by *Curcuma aromatica* at 93% and *Hydrocotyle asiatica* at 88%. The antioxidant activity of *Santalum album* is 97%, followed by Curcuma aromatica at 93% and Rubia tinctorum at 91%. *Curcuma aromatica* attains the highest efficacy in the antibacterial category at 93%, followed by *Tagetes erecta* at 87% and *Sapindus mukorossi* at 88%. In the realm of skin regeneration and anti-aging, *Santalum album* ranks highest at 97%, followed by *Curcuma aromatica* at 93% and *Hydrocotyle asiatica* at 88%. *Butea monosperma* is prominent in hair growth and scalp health at 89%, followed by *Sapindus mukorossi* at 88% and *Pongamia pinnata* at 84%. In depigmenting and skin lightening, *Rubia tinctorum* and *Chrysopogon zizanioides* both attain 91%, while *Curcuma aromatica* reaches 93%. *Butea monosperma* exhibits the highest efficacy for wound healing at 89%, followed by *Eclipta prostrata* at 83% and *Hydrocotyle asiatica* at 88%. *Santalum album* and *Lawsonia inermis* both achieve a moisturizing/skin conditioning efficacy of 97%, but Cocos nucifera demonstrates significant promise at 81%. *Acacia concinna* exhibits detoxifying qualities at 94%, whereas *Withania somnifera* excels in collagen enhancement at 82%. These plants, characterized by elevated FLs, underscore their medicinal importance in many pharmacological applications. Table 6 displays the FL scores according to the various pharmacological activities of the acquired species. Figure 6 depicts the representation of plant species exhibiting the greatest percentile for each pharmacological activity.

Table 6. FL score according to distinct pharmacological activities of obtained species

| **Pharmacological Activity** | **Plant Name** | **FL (%)** |
|---|---|---|
| Anti-inflammatory | *Aloe barbadensis* Mill. | 80% |
| | *Azadirachta indica* A. Juss. | 81% |
| | *Curcuma longa* L. | 75% |
| | *Santalum album* L. | 97% |
| | *Hibiscus rosa-sinensis* L. | 87% |
| | *Ocimum sanctum* L. | 71% |
| | *Withania somnifera* (L.) Dunal | 82% |
| | *Allium cepa* L. | 73% |
| | *Allium sativum* L. | 75% |
| | *Centella asiatica* (L.) Urb. | 69% |
| | *Eclipta prostrata* (L.) L. | 83% |
| | *Curcuma aromatica* Salisb. | 93% |
| | *Hydrocotyle asiatica* L. | 88% |
| | *Moringa oleifera* Lam. | 82% |
| | *Butea monosperma* (Lam.) Taub. | 89% |
| | *Terminalia arjuna* (Roxb. ex DC.) Wight & Arn. | 83% |
| | *Pongamia pinnata* (L.) Pierre | 84% |
| | Acorus calamus L. | 80% |
| | *Rubia cordifolia* L. | 78% |
| | *Hemidesmus indicus* (L.) R. Br. ex Schult. | 75% |
| Antioxidant | *Aloe barbadensis* Mill. | 80% |
| | *Azadirachta indica* A. Juss. | 81% |
| | *Curcuma longa* L. | 75% |
| | *Curcuma aromatica* Salisb. | 93% |
| | *Santalum album* L. | 97% |
| | *Hibiscus rosa-sinensis* L. | 87% |
| | *Ocimum sanctum* L. | 71% |
| | *Phyllanthus emblica* L. | 81% |
| | *Withania somnifera* (L.) Dunal | 82% |
| | *Glycyrrhiza glabra* L. | 78% |
| | *Acorus calamus* L. | 80% |
| | *Pongamia pinnata* (L.) Pierre | 84% |
| | *Sapindus mukorossi* Gaertn. | 88% |
| | *Cocos nucifera* L. | 81% |
| | *Butea monosperma* (Lam.) Taub. | 89% |
| | *Rubia tinctorum* L. | 91% |
| | *Terminalia chebula* Retz. | 73% |
| | *Syzygium cumini* (L.) Skeels | 83% |
| | *Moringa oleifera* Lam. | 72% |
| | *Carica papaya* L. | 75% |
| | *Terminalia bellirica* (Gaertn.) Roxb. | 71% |
| | *Momordica charantia* L. | 84 % |
| Antimicrobial | *Azadirachta indica* A. Juss. | 81% |
| | *Hibiscus rosa-sinensis* L. | 87% |
| | *Phyllanthus emblica* L. | 81% |
| | *Momordica charantia* L. | 84% |
| | *Allium cepa* L. | 73% |
| | *Allium sativum* L. | 75% |

| | | |
|---|---|---|
| | *Curcuma aromatica* Salisb. | 93% |
| | *Tagetes erecta* L. | 87% |
| | *Prunus amygdalus* Batsch | 76% |
| | *Eclipta prostrata* (L.) L. | 83% |
| | *Aegle marmelos* (L.) Corrêa | 80% |
| | *Syzygium cumini* (L.) Skeels | 83% |
| | *Terminalia chebula* Retz. | 73% |
| | *Hemidesmus indicus* (L.) R. Br. ex Schult. | 75% |
| | *Sapindus mukorossi* Gaertn. | 88% |
| Skin Rejuvenation / Anti-aging | *Aloe barbadensis* Mill. | 80% |
| | *Azadirachta indica* A. Juss. | 81% |
| | *Curcuma longa* L. | 75% |
| | *Santalum album* L. | 97% |
| | *Hibiscus rosa-sinensis* L. | 87% |
| | *Withania somnifera* (L.) Dunal | 82% |
| | *Ficus benghalensis* L. | 72% |
| | *Momordica charantia* L. | 84% |
| | *Carica papaya* L. | 75% |
| | *Centella asiatica* (L.) Urb. | 69% |
| | *Tagetes erecta* L. | 87% |
| | *Curcuma aromatica* Salisb. | 93% |
| | *Hydrocotyle asiatica* L. | 88% |
| | *Murraya koenigii* (L.) Spreng. | 80% |
| | *Rubia cordifolia* L. | 78% |
| | *Hemidesmus indicus* (L.) R. Br. ex Schult. | 75% |
| Hair Growth / Scalp Health | *Eclipta prostrata* (L.) L. | 83% |
| | *Murraya koenigii* (L.) Spreng. | 80% |
| | *Butea monosperma* (Lam.) Taub. | 89% |
| | *Pongamia pinnata* (L.) Pierre | 84% |
| | *Acorus calamus* L. | 80% |
| | *Rubia cordifolia* L. | 78% |
| | *Sapindus mukorossi* Gaertn. | 88% |
| Depigmenting / Skin Brightening | *Azadirachta indica* A. Juss. | 81% |
| | *Curcuma longa* L. | 75% |
| | *Curcuma aromatica* Salisb. | 93% |
| | *Phyllanthus emblica* L. | 81% |
| | *Carica papaya* L. | 75% |
| | *Syzygium cumini* (L.) Skeels | 83% |
| | *Terminalia bellirica* (Gaertn.) Roxb. | 71% |
| | *Terminalia chebula* Retz. | 73% |
| | *Rubia tinctorum* L. | 91% |
| | *Chrysopogon zizanioides* (L.) Roberty | 91% |
| | *Butea monosperma* (Lam.) Taub. | 89% |
| | *Pongamia pinnata* (L.) Pierre | 84% |
| Wound Healing | *Withania somnifera* (L.) Dunal | 82% |
| | *Centella asiatica* (L.) Urb. | 69% |
| | *Eclipta prostrata* (L.) L. | 83% |
| | *Hydrocotyle asiatica* L. | 88% |
| | *Rubia cordifolia* L. | 78% |
| | *Butea monosperma* (Lam.) Taub. | 89% |
| Moisturizing / Skin Conditioning | *Aloe barbadensis* Mill. | 80% |
| | *Rosa indica* L. | 75% |
| | *Santalum album* L. | 97% |

| | | |
|---|---|---|
| | *Lawsonia inermis* L. | 97% |
| | *Cocos nucifera* L. | 81% |
| | *Acorus calamus* L. | 80% |
| Detoxifying | *Hemidesmus indicus* (L.) R. Br. ex Schult. | 75% |
| | *Momordica charantia* L. | 84% |
| | *Acacia concinna* (Willd.) DC. | 94% |
| Collagen Boosting | *Withania somnifera* (L.) Dunal | 82% |
| | *Centella asiatica* (L.) Urb. | 69% |

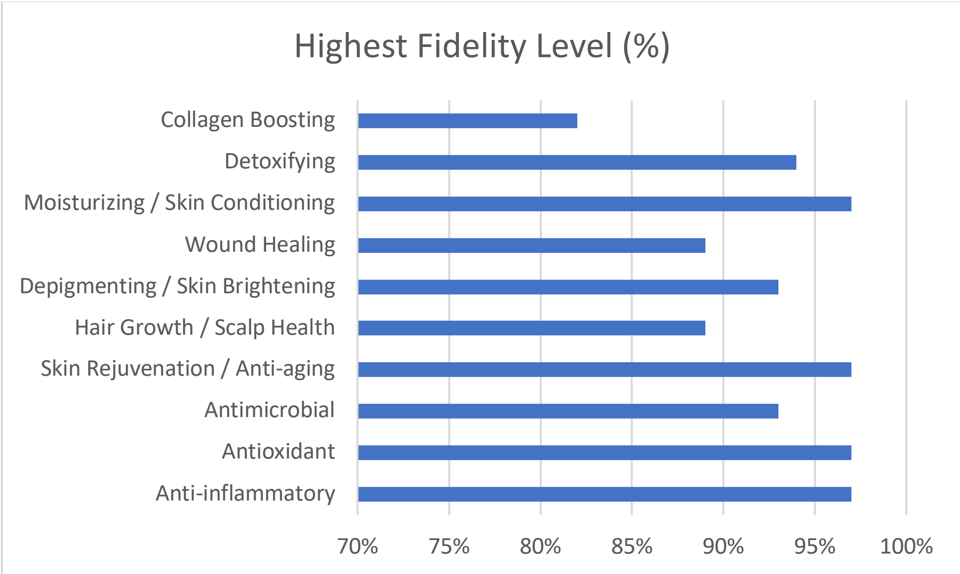


Figure 6. Categorization of plant species by pharmacological action based on FL analysis.

Table 7 provides comprehensive information on the chemical ingredients, modes of action, pharmacological activity, and relevant molecular signaling pathways of diverse plant species. Each item delineates the bioactive substances that provide various health benefits, including antioxidant, anti-inflammatory, antibacterial, and skin-healing qualities, while identifying critical molecular pathways, such as NF-κB, Nrf2, and MAPK, by which these effects are facilitated. This extensive collection highlights the varied medicinal possibilities of various herbs, especially in dermatological and hair care contexts.

Table 7. Scientific literature information of obtained species

| **Plant Name** | **Major Chemical Constituents** | **Mechanism of Action** | **Pharmacological Activity** | **Molecular Signalling Pathways** | **Reference** |
|---|---|---|---|---|---|
| *Aloe barbadensis* Mill. | Aloin, barbaloin, polysaccharides, vitamins C and E | Moisturizes skin via hydration; soothes inflammation by inhibiting COX-2 and prostaglandin synthesis. | Antioxidant, anti-inflammatory, wound healing. | Activates TGF-β and VEGF pathways to enhance skin repair. | Hakami *et al.* 2024 |
| *Azadirachta indica* A. Juss. | Azadirachtin, nimbidin, nimbin, quercetin, flavonoids | Reduces microbial growth and inflammation by inhibiting NF-κB activation; scavenges ROS. | Antimicrobial, antifungal, anti-inflammatory. | Modulates NF-κB, MAPK, and JAK-STAT pathways. | Shaheen *et al.* 2024 |

| | | | | | |
|---|---|---|---|---|---|
| *Curcuma longa* L. | Curcumin, demethoxycurcumin, bisdemethoxycurcumin | Suppresses oxidative stress and inflammation by inhibiting NF-κB and Nrf2 activation. | Antioxidant, anti-inflammatory, depigmenting. | Modulates Nrf2, NF-κB | Razavi *et al.* 2021 |
| *Santalum album* L. | Santalol, α-santalol, β-santalol, tannins | Inhibits melanin synthesis and oxidative stress; promotes collagen synthesis. | Antioxidant, skin lightening, anti-aging. | Modulates PI3K/Akt and Wnt/β-catenin pathways. | Levenson 2022 |
| *Hibiscus rosa-sinensis* L. | Anthocyanins, flavonoids, mucilage, polyphenols | Improves hair strength by inhibiting lipid peroxidation; promotes wound healing through increased collagen synthesis. | Antioxidant, hair growth promoter, wound healing. | Activates TGF-β and VEGF pathways for skin repair. | Albahri *et al.* 2024 |
| *Ocimum sanctum* L. | Eugenol, ursolic acid, rosmarinic acid, flavonoids | Reduces oxidative stress and microbial growth; soothes skin by suppressing pro-inflammatory cytokines. | Antioxidant, antimicrobial, adaptogenic. | Modulates NF-κB, MAPK, and JAK-STAT pathways. | Pillai & Antony 2024 |
| *Rosa indica* L. | Anthocyanins, quercetin, kaempferol, terpenes | Promotes hydration and reduces inflammation through its polyphenolic content; scavenges ROS. | Antioxidant, anti-inflammatory, soothing. | Activates Nrf2 and downregulates NF-κB pathways. | Singh *et al.* 2023 |
| *Phyllanthus emblica* L. | Emblicanin A and B, gallic acid, ellagic acid, vitamin C | Neutralizes free radicals and reduces melanin synthesis; inhibits tyrosinase activity. | Antioxidant, depigmenting, anti-inflammatory. | Activates Nrf2 pathway and inhibits NF-κB. | Jin-xi *et al.* 2023 |
| *Withania somnifera* (L.) Dunal | Withaferin A, withanolides, alkaloids, saponins | Improves skin elasticity by promoting collagen synthesis; reduces oxidative stress. | Adaptogenic, antioxidant, anti-inflammatory. | Modulates Nrf2 and NF-κB pathways. | Narra *et al.* 2023 |

| | | | | | |
|---|---|---|---|---|---|
| *Ficus benghalensis* L. | Triterpenoids, flavonoids, glycosides, tannins | Promotes scalp hydration and soothes skin by inhibiting pro-inflammatory mediators. | Anti-inflammatory, antioxidant, hair strengthener. | Modulates COX-2 and MAPK pathways. | Iltaf *et al.* 2021 |
| *Momordica charantia* L. | Charantin, momordicosides, alkaloids, polypeptide-P | Reduces inflammation and pigmentation by scavenging free radicals and inhibiting tyrosinase. | Antioxidant, anti-inflammatory, depigmenting. | Activates Nrf2 and inhibits NF-κB. | Zubair *et al.* 2018 |
| *Moringa oleifera* Lam. | Moringin, quercetin, kaempferol, vitamin A | Enhances skin elasticity and hydration by promoting collagen synthesis; reduces oxidative stress. | Antioxidant, anti-inflammatory, antimicrobial. | Activates TGF-β and Nrf2 pathways. | Nizioł-Łukaszewska *et al.* 2024 |
| *Lawsonia inermis* L. | Lawsone, flavonoids, tannins, gallic acid | Provides pigmentation through lawsone; reduces microbial growth and inflammation. | Antimicrobial, anti-inflammatory, cooling. | Modulates NF-κB and COX-2 pathways. | Gaur *et al.* 2017 |
| *Acacia concinna* (Willd.) DC. | Saponins, flavonoids, polyphenols | Cleanses scalp by reducing sebum and microbial load; enhances hair shine. | Antimicrobial, antioxidant, cleansing agent. | Reduces oxidative stress by scavenging ROS. | Rinthong *et al.* 2024 |
| *Aegle marmelos* (L.) Corrêa | Marmelosin, flavonoids, tannins, coumarins | Improves skin texture and elasticity; reduces oxidative damage through its antioxidant activity. | Antioxidant, anti-inflammatory, wound healing. | Activates Nrf2 and inhibits NF-κB. | Pynam *et al.* 2018 |
| *Glycyrrhiza glabra* L. | Glycyrrhizin, glabridin, flavonoids, saponins | Reduces inflammation and pigmentation by inhibiting tyrosinase activity and oxidative stress. | Anti-inflammatory, depigmenting, antimicrobial. | Inhibits NF-κB and regulates MAPK pathways. | Cerulli *et al.* 2022 |
| *Carica papaya* L. | Papain, carotenoids, flavonoids, vitamin C | Exfoliates skin by breaking down proteins; reduces pigmentation through antioxidant effects. | Exfoliating, antioxidant, anti-aging. | Modulates MAPK and Nrf2 pathways. | Oguntoye *et al.* 2023 |

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|---|---|---|---|---|---|
| *Prunus amygdalus* Batsch | Oleic acid, linoleic acid, vitamins A, D, and E | Moisturizes and nourishes the skin by promoting barrier repair; reduces dryness and irritation. | Skin conditioning, anti-inflammatory, moisturizing. | Activates PI3K/Akt and Nrf2 pathways. | Stierlin *et al.* 2018 |
| *Allium cepa* L. | Quercetin, sulfur compounds, flavonoids | Reduces oxidative stress and promotes collagen synthesis; inhibits inflammation through the suppression of NF-κB. | Anti-inflammatory, antimicrobial, collagen booster. | Inhibits NF-κB and modulates MAPK pathways. | Ismil *et al.* 2025 |
| *Allium sativum* L. | Allicin, sulfur compounds, flavonoids | Reduces microbial growth and inflammation by inhibiting COX-2 and TNF-α; promotes wound healing. | Antimicrobial, anti-inflammatory, wound healing. | Inhibits NF-κB and modulates JAK-STAT pathways. | Kadyrbayeva *et al.* 2021 |
| *Centella asiatica* (L.) Urb. | Asiaticoside, madecassoside, saponins, flavonoids | Promotes collagen production and wound healing; reduces inflammation by inhibiting TNF-α and IL-6. | Wound healing, anti-inflammatory, skin firming. | Activates TGF-β and PI3K/Akt pathways. | Seo *et al.* 2019 |
| *Tagetes erecta* L. | Lutein, zeaxanthin, flavonoids | Protects skin from oxidative damage and improves skin tone through its antioxidant properties. | Antioxidant, anti-aging, brightening. | Modulates Nrf2 and NF-κB pathways. | Meetong *et al.* 2023 |
| *Hydrocotyle asiatica* L. | Asiaticoside, madecassoside, tannins | Improves skin elasticity by stimulating collagen production; promotes wound healing and reduces inflammation. | Anti-aging, wound healing, anti-inflammatory. | Activates TGF-β and Nrf2 pathways. | Noppradit *et al.* 2024 |
| *Eclipta prostrata* (L.) L. | Ecliptine, wedelolactone, flavonoids | Reduces hair fall by improving blood circulation to hair follicles; promotes hair growth through stimulation of IGF-1 and FGF-7. | Hair growth promoter, anti-inflammatory, antioxidant. | Modulates Wnt/β-catenin and MAPK pathways. | Timalsina *et al.* 2021 |

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|---|---|---|---|---|---|
| *Chrysopogon zizanioides* (L.) Roberty | Vetiverol, vetivone, antioxidants | Moisturizes and soothes skin by inhibiting pro-inflammatory mediators; improves skin texture. | Moisturizing, anti-inflammatory, skin calming. | Modulates NF-κB and MAPK pathways. | Kurrimboccus *et al.* 2022 |
| *Murraya koenigii* (L.) Spreng. | Murrayanol, β-sitosterol, flavonoids | Enhances scalp health by reducing dandruff and improving circulation; reduces oxidative stress. | Antioxidant, anti-inflammatory, scalp health promoter. | Activates Nrf2 and modulates NF-κB pathways. | Huda *et al.* 2022 |
| *Syzygium cumini* (L.) Skeels | Eugenol, anthocyanins, ellagic acid, tannins | Reduces pigmentation by inhibiting melanin synthesis and scavenging free radicals. | Depigmenting, antioxidant, antimicrobial. | Modulates Nrf2 and NF-κB pathways. | Ashmawy *et al.* 2023 |
| *Terminalia bellirica* (Gaertn.) Roxb. | Gallic acid, ellagic acid, tannins, flavonoids | Antioxidant and anti-inflammatory effects; scavenges free radicals and reduces oxidative stress. | Antioxidant, anti-aging, skin lightening, anti-inflammatory. | Modulates Nrf2, NF-κB, and MAPK pathways. | Choi 2022 |
| *Terminalia chebula* Retz. | Tannins, anthraquinones, flavonoids, vitamin C, phenolic acids | Exhibits antimicrobial, anti-inflammatory, and skin-conditioning effects; improves skin texture and elasticity. | Antioxidant, antimicrobial, anti-inflammatory, skin conditioning. | Modulates NF-κB, MAPK, and Nrf2 pathways. | Liang *et al.* 2024 |
| *Terminalia arjuna* (Roxb. ex DC.) Wight & Arn. | Triterpenoids, flavonoids, quercetin, gallic acid, ellagic acid, tannins | Improves skin elasticity and reduces oxidative stress; enhances circulation and strengthens the skin barrier. | Antioxidant, anti-aging, skin firming, wound healing. | Modulates TGF-β, MAPK, and PI3K/Akt pathways. | Perera *et al.* 2024 |
| *Rubia cordifolia* L. | Anthraquinones, purpurin, alizarin | Reduces pigmentation and inflammation; promotes wound healing through enhanced collagen synthesis. | Depigmenting, wound healing, anti-inflammatory. | Activates TGF-β and modulates NF-κB pathways. | Gorle & Patil 2018 |

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|---|---|---|---|---|---|
| *Hemidesmus indicus* (L.) R. Br. ex Schult. | Hemidesmin, saponins, flavonoids | Reduces inflammation and microbial growth by suppressing NF-κB and COX-2. | Anti-inflammatory, antimicrobial, detoxifying. | Modulates NF-κB and MAPK pathways. | Moorthy *et al.* 2021 |
| *Rubia tinctorum* L. | Alizarin, purpurin, anthraquinones | Reduces pigmentation and improves skin texture by stimulating collagen synthesis and inhibiting tyrosinase. | Depigmenting, anti-aging, antioxidant. | Modulates NF-κB and Wnt/β-catenin pathways. | Hoseinzadeh *et al.* 2020 |
| *Butea monosperma* (Lam.) Taub. | Butrin, isobutrin, flavonoids, tannins | Reduces oxidative stress and improves circulation to the scalp, promoting hair growth. | Hair growth promoter, anti-inflammatory, antioxidant. | Modulates NF-κB and PI3K/Akt pathways. | Kakatum & Sudjaroen, 2021 |
| *Cocos nucifera* L. | Lauric acid, capric acid, Vitamin E | Hydrates and nourishes the skin by improving moisture retention; promotes wound healing. | Moisturizing, anti-inflammatory, skin barrier repair. | Activates PI3K/Akt and MAPK pathways. | Mahbub *et al.* 2022 |
| *Sapindus mukorossi* Gaertn. | Saponins, flavonoids, fatty acids, polysaccharides | Detergent and surfactant properties; cleanses the skin by emulsifying oils and removing dirt and impurities. | Antimicrobial, cleansing, skin conditioner. | Modulates MAPK, PI3K/Akt pathways. | Chen *et al.* 2019 |
| *Pongamia pinnata* (L.) Pierre | Pongamol, karanjin, flavonoids, triterpenoids | Improves scalp health by reducing microbial growth and inflammation; promotes hair growth through VEGF stimulation. | Hair growth promoter, antimicrobial, anti-inflammatory. | Modulates VEGF and NF-κB pathways. | Devidas *et al.* 2024 |
| *Acorus calamus* L. | β-Asarone, α-asarone, flavonoids | Reduces oxidative damage and pigmentation; soothes the skin by reducing inflammation. | Antioxidant, anti-inflammatory, skin soothing. | Modulates Nrf2 and NF-κB pathways. | Zhao *et al.* 2023 |

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|---|---|---|---|---|---|
| *Curcuma aromatica* Salisb. | Curcumin, demethoxycurcumin, bisdemethoxycurcumin | Reduces skin pigmentation and inflammation by inhibiting tyrosinase and NF-κB activation. | Depigmenting, anti-inflammatory, antioxidant. | Modulates Nrf2 and NF-κB path | Pabuprapap *et al.* 2022 |

## Discussion

The demographic composition of participants is a critical factor in ethnobotanical surveys, as it influences the identification of plants with phytocosmetic potential. Regional representation reflects geographic and cultural factors that shape traditional practices, with areas of high participation often indicating rich biodiversity or strong traditional knowledge systems (Mahomoodally et al. 2016). Gender distribution highlights social roles in knowledge sharing; although men often dominate surveys due to leadership roles, women, who are primary users of cosmetic plants, are often underrepresented despite their major contributions to skincare and hygiene practices (Gang and Kang 2022). Occupational variety adds depth to findings, with herbalists providing valuable practical insights into local plant use. The limited involvement of formally trained Ayurvedic practitioners suggests a disconnect between community practices and institutional systems, indicating the need for better integration to expand the scope of phytocosmetic research (Ezekwem 2023). Age is also significant, as older participants safeguard traditional knowledge passed down through generations and play a key role in preserving rare cultural practices (Hendriyani et al. 2024). Educational diversity further enriches the data, as both literate and non-literate individuals contribute important perspectives. A diverse participant base strengthens ethnobotanical data and supports the discovery of culturally important and scientifically useful plants for natural cosmetic applications (Rocha et al. 2017; Sultan et al. 2021). The ethnobotanical traditions of tribal tribes in Western Odisha demonstrate a deep comprehension of plant-derived phytocosmetics, integrating tradition with sustainable utilization of natural resources. These techniques illustrate the application of plant-derived bioactive chemicals in skincare, hair care, and personal hygiene, highlighting their significance in contemporary dermatological science. Aloe vera contains polysaccharides, including acemannan and glucomannan, which demonstrate hydrating and wound-healing properties. These chemicals enhance fibroblast activity, facilitating collagen synthesis and expediting skin restoration (Witaszczyk et al. 2023). Moreover, its anti-inflammatory properties, facilitated by the suppression of prostaglandin E2 and cytokine release, render it essential for acne treatment and the alleviation of irritated skin (Chen et al. 2024). Neem (*Azadirachta indica*) is esteemed for its extensive antibacterial capabilities, which are ascribed to bioactive components including nimbidin, azadirachtin, and quercetin. These phytochemicals compromise microbial cell membranes, demonstrating effectiveness against pathogens that cause skin diseases (Baby et al. 2022). Moreover, neem's antioxidative properties, derived from its abundant phenolic compounds, counteract reactive oxygen species (ROS), so averting oxidative damage and aging (Dang et al. 2024). Turmeric (*Curcuma longa*) includes curcuminoids, especially curcumin, which regulate many molecular pathways, including NF-κB and MAPK, to produce anti-inflammatory, depigmenting, and antioxidant actions. These properties are augmented by synergistic formulations containing milk and honey, which facilitate nutrient delivery and hydration (Razavi et al. 2021).

Hibiscus (*Hibiscus rosa-sinensis*), a foundational component in traditional cosmetic formulations, is rich in flavonoids and mucilage, which contribute to its emollient, moisturizing, and anti-aging effects. The presence of phytosterols and polyphenols further supports hair follicle stimulation, promoting hair growth and reducing scalp inflammation and irritation through anti-inflammatory and antioxidant mechanisms (Enechukwu et al. 2022). Tulsi (*Ocimum sanctum*), widely valued in Ayurvedic skin remedies, contains eugenol and rosmarinic acid, which are potent antioxidants that mitigate oxidative stress and exhibit broad-spectrum antimicrobial activity. This dual action makes tulsi especially effective in managing acne, controlling sebum production, and treating microbial skin infections. The Indian rose (*Rosa indica*) contains an array of phenolic compounds and essential oils that support skin regeneration, toning, and hydration. Its anti-inflammatory properties stem from its ability to inhibit histamine release, making it useful for calming irritated or sensitive skin. Moreover, its natural aromatic profile enhances product appeal without the need for synthetic fragrances, supporting the development of clean-label cosmetic products (Hanumanthaiah et al. 2020). Less commonly used plants such as vetiver (*Chrysopogon zizanioides*) and gotu kola (*Centella asiatica*) offer unique dermatological benefits supported by their distinct phytochemical profiles. Vetiver roots are a source of sesquiterpenes and vetiverol, compounds known for their antioxidant and anti-inflammatory activity, making them ideal for formulations like foot washes, sunscreens, and anti-aging serums. These constituents protect against UV-induced oxidative damage and help strengthen the skin barrier, which is critical in preventing trans-epidermal water loss (Motule et al. 2021). Gotu kola, rich in asiaticoside and madecassoside, has been shown to stimulate collagen synthesis and promote angiogenesis through modulation of the TGF-β signaling pathway. These actions accelerate wound healing, reduce scarring, and improve skin elasticity, making it an increasingly popular ingredient in dermatocosmetic and post-surgical care products (Ago 2020).

Henna (*Lawsonia inermis*) is a cornerstone in traditional hair care systems, primarily due to its active compound, lawsone, which binds effectively with hair keratin to provide natural pigmentation and deep conditioning. Beyond its coloring properties, henna exhibits strong antifungal activity, making it beneficial in managing scalp disorders such as dandruff and seborrheic dermatitis. Its antioxidant capacity also helps in protecting hair fibers from oxidative damage, contributing to improved hair strength and luster (Jen et al. 2023). Soapnut (*Sapindus mukorossi*) and shikakai (*Acacia concinna*) are widely recognized for their high saponin content, which functions as a gentle, plant-based surfactant. These natural cleansers maintain the scalp's lipid balance while effectively removing dirt and excess oil, thereby minimizing dandruff and promoting overall hair health. Additionally, their anti-inflammatory potential, attributed to the inhibition of the cyclooxygenase (COX) enzyme, supports the reduction of scalp irritation and flakiness, making them suitable for sensitive skin formulations (Sang et al. 2023). Sandalwood (*Santalum album*) holds a significant place in dermatological and cosmetic traditions due to its rich content of α-santalol and β-santalol. These sesquiterpenoids exhibit pronounced antibacterial, anti-inflammatory, and soothing effects through modulation of key molecular pathways such as NF-κB and MAPK. Sandalwood paste is particularly effective in calming erythema, soothing sunburns, and reducing hyperpigmentation. Emerging studies also support its potential in anti-aging skincare, as it helps to prevent collagen degradation and enhance skin hydration. In addition to its cleansing role, *Acacia concinna* offers detoxifying properties that contribute to improved scalp health by facilitating the removal of environmental toxins and excess sebum. Its antimicrobial action protects against follicular infections, and its mild acidity helps maintain the natural pH of the scalp. Recent insights also suggest its potential in restoring scalp microbiota balance, which is increasingly recognized as a factor in sustainable scalp and hair care (Pullaiah et al. 2023).

The pharmacological properties of plants such as *Curcuma longa*, *Santalum album*, *Lawsonia inermis*, and *Rubia tinctorum* are strongly supported by their longstanding folkloric use, which has been validated by modern scientific studies. *Santalum album* demonstrates potent anti-inflammatory and antioxidant activity, while *Curcuma longa* is widely known for its skin-brightening, anti-aging, and wound-healing properties. These effects are mediated through well-established molecular mechanisms, including activation of the Nrf2 pathway, which enhances cellular defense against oxidative stress, and suppression of NF-κB signaling, which reduces inflammation and promotes tissue repair (Chaiprasongsuk et al. 2023). Quantitative ethnobotanical indices such as Informant Consensus Factor (IP), Use Reports (UR), and Use Value (UV) highlight the depth of traditional knowledge and the high cultural significance attributed to these species. The high metrics associated with *Santalum album* and *Lawsonia inermis* reflect their pharmacological versatility and continued relevance in traditional and modern dermatological applications. Furthermore, the integration of less commonly used species like *Rubia tinctorum*, known for its skin-depigmenting effects via tyrosinase inhibition, and *Hydrocotyle asiatica*, which supports dermal matrix remodeling and collagen synthesis, illustrates a sophisticated level of ethnopharmacological understanding within these communities (Michalak 2023). These species not only contribute to culturally rooted skincare practices but also hold potential for formulation in evidence-based cosmeceuticals.

The conservation of ethnobotanically significant plants in Western Odisha is vital for preserving both biodiversity and the region's rich cultural heritage. Effective conservation strategies should prioritize community engagement, leveraging local knowledge while promoting sustainable harvesting practices. Involving indigenous and tribal groups as key stakeholders in participatory conservation programs ensures the ethical preservation of traditional wisdom. Initiatives such as community-managed nurseries, seed banks, and regulated harvesting zones for species like *Aloe vera*, *Santalum album*, and *Curcuma longa* are critical to maintaining long-term availability. Reforestation using native species, coupled with educational campaigns on ecological stewardship, can mitigate threats like habitat loss and overexploitation. Importantly, aligning these localized efforts with global sustainability frameworks, such as the United Nations Sustainable Development Goals (SDGs), particularly those focused on climate resilience, land restoration, and responsible consumption, which can amplify impact and attract broader institutional support (Mathura et al. 2022; Oduor et al. 2024). These integrated approaches create a sustainable pathway for conserving ethnobotanical resources while promoting innovation in plant-based cosmetics and wellness industries.

In the field of cosmeceuticals, these plants provide significant potential for additional formulation and commercialization. Utilizing bioactive components, like curcuminoids from *Curcuma longa*, saponins from *Sapindus mukorossi*, and flavonoids from *Hibiscus rosa-sinensis*, can facilitate the creation of novel, natural skincare and haircare products (Hoang et al. 2021). Advanced extraction methods, such as green solvent extraction and supercritical fluid extraction, can enhance the yield and purity of bioactives, hence ensuring their effectiveness in formulations. Nanotechnology-driven delivery methods, such nanoemulsions and liposomes, can improve the stability and bioavailability of these substances, resulting in enhanced cosmeceutical uses (Park et al. 2021). Integrating traditional formulations with contemporary pharmacological knowledge can reconcile legacy and science, resulting in a sustainable and efficacious product line for worldwide markets. Pharmacological investigations on plants such as *Curcuma longa*, *Aloe barbadensis*, and *Santalum album* have revealed a broad range of effects, including anti-inflammatory, antioxidant, antibacterial, and wound-healing characteristics. The *Santalum album* exhibits significant antioxidant activity via the Nrf2 signaling pathway, mitigating oxidative stress and promoting skin regeneration. *Curcuma longa* demonstrates anti-inflammatory effects through NF-κB regulation, rendering it effective for the treatment of inflammatory skin disorders (Lohakul et al. 2021). Aloe vera, recognized for its moisturizing and soothing properties, functions by regulating cytokine activity, thereby facilitating wound healing and collagen production. These pharmacological effects not only corroborate traditional applications but also establish a basis for the development of tailored therapies for dermatological disorders. Comprehensive in-vivo and in-vitro investigations, along with clinical trials, are important to validate these activities and guarantee their safety and efficacy for wider applications (Lee et al. 2024). Western Odisha, characterized by its distinctive biodiversity and cultural wealth, might exemplify sustainable ethnobotanical development. Conservation initiatives should include habitat restoration, regulation of plant collecting methods, and the cultivation of high-demand species in controlled settings (Singh et al. 2021). Partnerships with academic institutions and industries can enhance research on plant bioactives and support community-based enterprises that benefit local economies. Moreover, legislative frameworks that safeguard the intellectual property rights of indigenous knowledge holders and establish equitable benefit-sharing systems might enhance conservation incentives.

## Conclusion

This study presents a comprehensive ethnobotanical examination of plant-based cosmetic practices among tribal tribes in Western Odisha, yielding significant insights into the medicinal and cultural significance of indigenous phytocosmeceuticals. Comprehensive research with 112 informants across six districts resulted in the identification and documentation of 39 plant species from 33 families for their uses in personal care. These uses encompass skincare, microbial infection treatment, age-related skin management, scalp health, and hair care. The extensive and recurrent utilization of these plants among the communities indicates a profound comprehension of their advantages, acquired over years of observation, experience, and traditional knowledge. The importance of these plants is further emphasized by their elevated scores in ethnobotanical indices, including usage value, relative frequency of citation, and fidelity level. These metrics illustrate the cultural significance and therapeutic efficacy of specific species, including *Santalum album*, *Curcuma aromatica*, and *Rubia tinctorum*. The pharmacological attributes of these plants are corroborated by contemporary scientific research, demonstrating that numerous species exert their biological effects via distinct cellular routes. This encompasses the suppression of nuclear factor kappa B, a principal modulator of inflammation, and the activation of nuclear factor erythroid 2-related factor 2, which is crucial for antioxidant defense. Collectively, these processes substantiate the dermatological efficacy of these species and provide a scientific basis for their ongoing application and further advancement. Conventional processes for crafting these cosmetics, such as the extraction of botanical components, amalgamation with natural additives, and application methods, exhibit a refined empirical comprehension of formulation. These techniques enhance both the efficacy and durability of the products while also demonstrating the community's sustainable attitude to natural resource utilization. Numerous remedies utilize readily available substances such as milk, honey, turmeric, rose water, neem, and aloe vera, highlighting a focus on safety, cost-effectiveness, and ecological sustainability. This study's results underscore the pressing necessity for conservation initiatives to safeguard both plant biodiversity and traditional knowledge. Community-based nurseries, seed preservation banks, and regulated harvesting techniques are vital for securing the supply of crucial medicinal plants for future generations. These efforts require institutional structures that acknowledge the rights of indigenous groups and encourage the ethical use of their intellectual contributions. Equitable benefit-sharing strategies are essential to guarantee that local knowledge holders obtain proper recognition, economic advantages, and sustained participation in the development and commercialization of natural cosmetic goods. Moreover, the amalgamation of traditional wisdom with contemporary scientific advancements presents significant opportunities for the beauty and wellness sectors. Progress in biotechnology, formulation science, and dermatological research can improve the safety, efficacy, and marketability of these botanical products. Future investigations should concentrate on the extraction of bioactive substances, preclinical and clinical assessments, and the formulation of standardized techniques for product manufacture. Cooperative initiatives among scholars, tribal communities, and industry stakeholders can facilitate the sustainable and respectful conversion of ethnobotanical heritage into globally pertinent personal care products.

## Declarations

**List of abbreviation:** UV: Use value; IP: Informant participants;RFC: Relative frequency citation;CI: Cultural index;UR: Use report;FL: Fidelity level;COX-2: Cyclooxygenase-2;NF-κB: Nuclear Factor Kappa B;ROS: Reactive Oxygen Species;MAPK: Mitogen-Activated Protein Kinase;JAK-STAT: Janus Kinase-Signal Transducer and Activator of Transcription;VEGF: Vascular Endothelial Growth Factor;TGF-β: Transforming Growth Factor Beta;PI3K/Akt: Phosphoinositide 3-Kinase/Protein Kinase B;TNF-α: Tumor Necrosis Factor Alpha;IGF-1: Insulin-Like Growth Factor 1;FGF-7: Fibroblast Growth Factor 7;Wnt/β-catenin: Wnt Signaling Pathway/β-Catenin Pathway;Nrf2: Nuclear Factor Erythroid 2-Related Factor 2. ;SDG: Sustainable development goals

**Ethics approval and consent to participate:** Verbal prior informal information consent was obtained before the survey

**Consent for publication:** People who participated in this study gave their prior informed consent for the publication of the article. All prople shown in images gave their consent to have the image published.

**Availability of data and material:** All the supporting data available in the article

**Competing interests**: The author declared no competing interests

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**Author's Contribution:** B.A designed and analyzed the data and framed the final manuscript. B.A, A.B. & P.M. prepared and proofread the manuscript. S.S, A.B, D.P.M. & T.P. carried out the survey and collected the data. All authors read and approved the final manuscript.

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