Ethnobotanical investigations of medicinal plants with antimicrobial, antioxidant, analgesic and anti-inflammatory potential in Khordha District, Odisha, India

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Research

Abstract

Background: Ethnobotanical knowledge remains a cornerstone of healthcare in rural and tribal communities, where medicinal plants are used to treat infections, pain, inflammation, and oxidative stress-related disorders. Khordha district of Odisha, with its rich ecological diversity, preserves a unique repertoire of traditional plant-based practices that require systematic documentation and validation.

Methods: An ethnobotanical survey was conducted among 90 informants across eight localities of Khordha using structured interviews, participant observation, and field collections. Voucher specimens were taxonomically authenticated. Quantitative indices, including Use Value, Relative Frequency of Citation, Cultural Importance Index, and Fidelity Level, were employed to assess the ethnomedicinal significance of each species.

Results: A total of 40 medicinal plants belonging to 24 families were recorded. *Azadirachta indica*, *Curcuma longa*, *Zingiber officinale*, *Tinospora cordifolia*, *Withania somnifera*, and *Phyllanthus emblica* were among the most frequently cited. Notably, *Filicium decipiens* exhibited the highest RFC (0.988) and CI (0.978), underscoring its strong cultural acceptance and therapeutic value. The majority of plants were employed for antimicrobial purposes (e.g., neem, garlic), antioxidant effects (e.g., amla, Triphala fruits), analgesic relief (e.g., *Withania somnifera*, *Zingiber officinale*), and anti-inflammatory actions (e.g., turmeric, Cassia fistula). Leaves were the most commonly used plant part, followed by roots, fruits, and rhizomes, with preparations ranging from pastes and decoctions to powders and infusions.

Conclusion: The study emphasises the ethnobotanical wealth of Khordha district, highlighting *Filicium decipiens* alongside widely known medicinal plants. These species, traditionally used for antimicrobial, antioxidant, analgesic, and anti-inflammatory purposes, represent a valuable resource for future pharmacological research, biodiversity conservation, and the development of integrative healthcare.

Keywords: Ethnobotany; Asteraceae, Indigenous communities; Human diseases, Herbal medicine

Background

Ethnobotany is the systematic study of the relationships between people and plants, focusing on how communities recognise, utilise, and conserve plant resources for diverse purposes, including food, medicine, rituals, and economic livelihood (Magare *et al.* 2025). Across India, this knowledge forms a cornerstone of traditional healthcare systems, particularly in rural areas where modern medical facilities are limited. The reliance on plants for therapeutic purposes is not merely a cultural practice; it represents a cost-effective, eco-friendly, and sustainable strategy for maintaining human health (Zouraris *et al.* 2025). In recent years, such indigenous knowledge has attracted global scientific attention due to its potential to yield bioactive compounds for drug discovery and natural product-based therapies. Khordha district of Odisha, geographically situated between 19°40′ and 20°25′ N latitude and 84°56′ and 85°34′ E longitude, is a biologically diverse region where a significant portion of the rural and peri-urban population continues to depend on medicinal plants for primary healthcare (Ravichandran *et al.* 2025).

The district's ecological diversity underpins the richness of its plant resources. Khordha encompasses urban centres like Khordha Town and Jatni, semi-urban settlements, fertile agrarian plains, forested areas adjacent to the Chandaka-Dampara Wildlife Sanctuary, and wetland ecosystems near Balugaon and Banapur along Chilika Lake (Pattnaik *et al.* 2024). Such varied habitats support a rich flora of medicinal plants, which are sourced from homestead gardens, temple groves, roadside margins, agricultural bunds, and semi-wild patches. Indigenous and tribal communities, including the Kondha, Saora, and other local tribal groups residing in peripheral forested or semi-forested areas, have been instrumental in conserving this ethnobotanical knowledge (Pattanayak *et al.* 2025). These communities possess a nuanced understanding of plant species, including their seasonal availability, part usage, preparation methods, and therapeutic efficacy, often transmitted orally through elders, traditional healers (Vaidyas), midwives, and community leaders (Behera *et al.* 2023).

Among the wide spectrum of therapeutic applications, plants with antimicrobial, antioxidant, analgesic, and anti-inflammatory properties are of primary importance. These categories address some of the most pressing health challenges in rural Odisha, such as infections, inflammation, oxidative stress-related conditions, and occupational musculoskeletal disorders (Acharya *et al.* 2024). Antimicrobial plants like *Azadirachta indica* (Neem), *Allium sativum* (Garlic), and *Lawsonia inermis* (Henna) are employed to manage wound infections, skin diseases, and waterborne illnesses. Decoctions of *Tinospora cordifolia* (Guduchi) and *Andrographis paniculata* (Kalmegh) are routinely administered to treat fevers and microbial infections, reflecting their immunomodulatory and antibacterial properties. These plants not only serve individual health needs but also contribute to community resilience, especially in tribal villages where access to formal healthcare remains sporadic (Ralte *et al.* 2024).

The antioxidant potential of ethnobotanical plants is another critical aspect of traditional medicine. Chronic diseases such as diabetes, cardiovascular disorders, and age-related degenerative conditions are increasingly prevalent, and oxidative stress is a key underlying factor. Plants such as *Phyllanthus emblica* (Amla), *Terminalia chebula* and *Terminalia bellirica* (components of Triphala), and *Moringa oleifera* leaves are widely used to mitigate oxidative damage (Mandal *et al.* 2025). These species are rich in ascorbic acid, polyphenols, flavonoids, and tannins, which scavenge free radicals and enhance endogenous enzymatic activity, including superoxide dismutase and catalase. Among tribal populations, Amla and Triphala are also integrated into daily dietary practices, demonstrating how medicinal and nutritional roles converge (Banik *et al.* 2020).

Analgesic and anti-inflammatory plants occupy an important place in communities dependent on manual labor, agriculture, and fishing. Topical pastes prepared from *Plumbago zeylanica* roots or *Achyranthes aspera* leaves are applied to manage rheumatic pain, while decoctions of *Zingiber officinale* (Ginger) and *Curcuma longa* (Turmeric) are used for joint and muscular discomfort (Das *et al.* 2022). Tribal healers often combine these plants with oils and other botanicals such as *Hibiscus rosa-sinensis*, *Eclipta prostrata*, and *Mentha arvensis* to enhance efficacy. Modern pharmacology validates many of these practices: curcumin inhibits NF-κB signaling, allicin disrupts microbial membranes, and azadirachtin suppresses pathogen growth (Allegra 2019). This convergence of traditional wisdom and molecular science reinforces the relevance of ethnobotanical knowledge in contemporary healthcare.

Cultural practices further enrich the medicinal landscape of Khordha. Ritualistic plant use—such as *Ocimum sanctum* (Tulsi) and *Datura metel*—often complements therapeutic applications for respiratory ailments, fever, and gastrointestinal disorders (Naz *et al.* 2017). Sacred groves and temple gardens serve as reservoirs of both biological and cultural diversity, ensuring the conservation of key species while embedding their use within socially meaningful practices. For tribal and rural communities, this dual role fosters sustainable utilization and local stewardship of plant resources (López *et al.* 2022).

Documenting these practices aligns with broader goals of biodiversity conservation, public health, and sustainable development. Ethnobotanical studies not only safeguard indigenous knowledge against erosion due to urbanization and changing lifestyles but also provide a foundation for bioprospecting and drug discovery (Ravipati *et al.* 2012). Moreover, such documentation contributes to achieving several Sustainable Development Goals (SDGs), including SDG 3 (Good Health and Well-Being), SDG 12 (Responsible Consumption and Production), SDG 15 (Life on Land), and SDG 2 (Zero Hunger) by promoting plant-based nutrition, sustainable harvesting, and community engagement in healthcare solutions. The integration of traditional plant-based remedies with modern medicine can alleviate economic burdens on rural households while fostering ecological stewardship (Vasarri *et al.* 2025).

The objective of this work is to document and analyze the traditional knowledge of medicinal plants in Khordha district, Odisha, focusing on species with antimicrobial, antioxidant, analgesic, and anti-inflammatory properties. It aims to highlight their therapeutic uses, cultural significance among local and tribal communities, and potential contributions to sustainable healthcare and biodiversity conservation. Based on these objectives, the study also aims to examine the relationship between cultural recognition and the pharmacological relevance of the documented species. It is hypothesized that plants cited for multiple therapeutic purposes will exhibit higher Cultural Importance (CI) and Relative Frequency of Citation (RFC) indices, reflecting their broader acceptance and utility within the community. Furthermore, it is anticipated that species with high RFC and CI values will correspond to strong pharmacological or bioactive evidence as reported in the scientific literature, thereby linking traditional ethnobotanical prominence with empirical validation.

Materials and Methods

Study Location

Khordha district, located in the eastern state of Odisha, India, lies between 19°40′ and 20°25′ N latitude and 84°56′ and 85°34′ E longitude. It forms part of the coastal plain region of Odisha, encompassing a mix of urban, semi-urban, and rural landscapes. The district headquarters, Khordha Town, along with Jatni and surrounding semi-urban areas, serve as administrative and commercial hubs, while numerous villages and agrarian settlements spread across fertile plains form the primary residence of local and tribal populations (Sahoo 2024). Ecologically, Khordha is highly diverse. The district hosts forest patches near Chandaka-Dampara Wildlife Sanctuary, which provide habitat for rich flora and fauna. Wetlands and riverine ecosystems near Balugaon and Banapur, located adjacent to Chilika Lake—the largest coastal lagoon in India—support unique plant species and serve as important resource areas for local communities. The region's homestead gardens, temple groves, agricultural bunds, and roadside margins further contribute to plant diversity, often acting as sites for the cultivation and preservation of medicinal species. The population includes various tribal groups, such as the Kondha and Saora, alongside non-tribal rural communities (Das *et al.* 2024). These groups rely extensively on local plant resources for food, medicine, and rituals. Tribal and rural households often maintain knowledge of seasonal availability, plant parts, preparation methods, and traditional therapeutic practices, which are frequently passed down through generations orally. The combination of ecological richness, cultural diversity, and traditional knowledge systems makes the Khordha district a valuable site for ethnobotanical studies. Its landscapes and communities provide insights into sustainable plant utilization, conservation practices, and the integration of traditional medicine into rural healthcare frameworks (Behera *et al.* 2024). The map of the study area is depicted in Fig. 1.

Survey and Data Collection

Ethnobotanical data were collected through structured and semi-structured interviews, participant observation, and field visits. A total of 90, including traditional healers (Vaidyas), midwives, elderly community members, and knowledgeable farmers, were consulted. Interviews focused on local plant names, plant parts used, preparation methods (decoction, paste, infusion, topical application), therapeutic uses, dosage, administration routes, and cultural significance.

Plant Collection and Identification

Medicinal plants reported by informants were collected from homestead gardens, temple groves, agricultural fields, roadside margins, and forested areas. Voucher specimens were prepared, labeled, and identified using standard taxonomic references such as Flora of Odisha and verified at the Department of Botany, Centurion University of Technology and Management, Odisha. Specimens were deposited in the departmental herbarium for future reference.

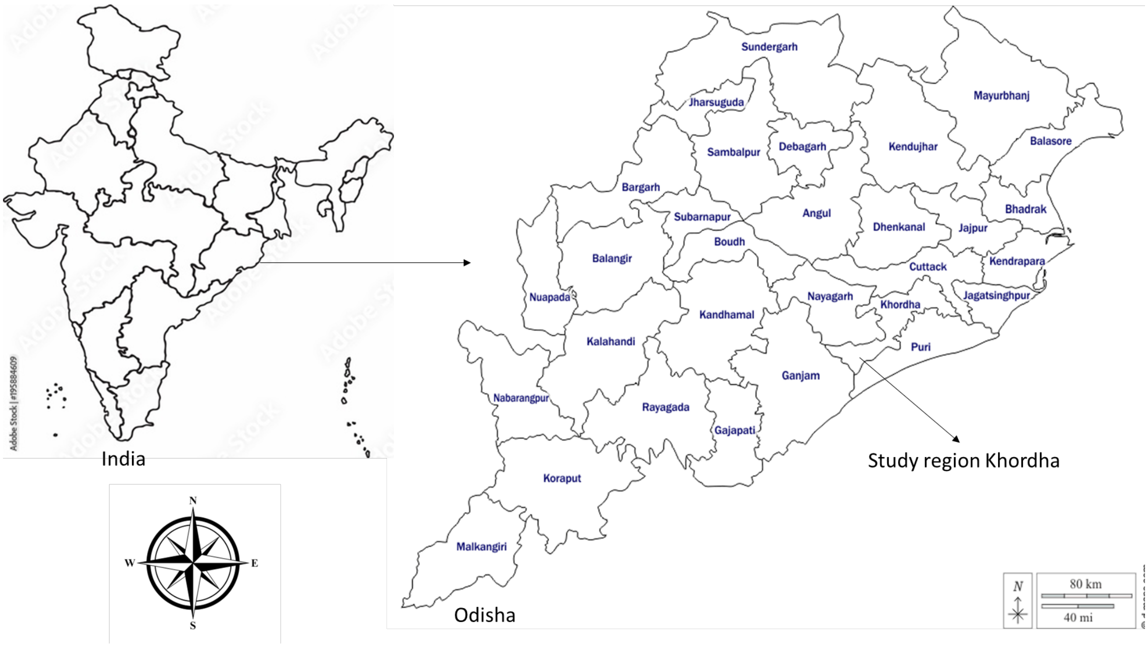

Figure 1. Map of the study area

Data analysis

To evaluate the ethnobotanical data collected on traditionally used antidiabetic plants, we employed several quantitative indices that help measure the significance and cultural relevance of each species. One of the key tools used was the Use Value (UV), which quantifies how frequently a particular plant is mentioned by informants in relation to its therapeutic applications. This index offers insight into the prominence of each species within the community's traditional knowledge system. The UV was calculated by dividing the total number of use reports for each plant by the number of informants participating in the study, thus indicating both the popularity and versatility of the plant in managing diabetes. This method helps identify plants that are not only widely recognized but also potentially involved in synergistic interactions within polyherbal formulations (Jishtu *et al.* 2025).

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

where ∑U denotes the total number of use reports for a given species, and N represents the total number of informants interviewed. This index helps highlight plants that are widely recognized and used in multiple contexts, indicating their versatility and embeddedness in local health practices. We recorded the Use Report (UR) as the aggregate number of times a particular plant species was mentioned by informants for its therapeutic applications, reflecting its overall prominence within the community (Jena 2025). To evaluate the level of agreement among informants about the medicinal relevance of specific plants, we also calculated the Relative Frequency of Citation (RFC), which serves as an indicator of shared traditional knowledge. The RFC was determined using the formula

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

where FC represents the number of informants who cited the species, and N is the total number of informants interviewed. We employed the Cultural Importance Index (CI) to assess the overall ethnobotanical relevance of each plant species by accounting for both the number of informants citing a species and the diversity of its reported uses across different therapeutic contexts. This metric provided a broader perspective on how individual plant species are integrated into the community's traditional healthcare practices. The CI was calculated using the formula (Ullah *et al.* 2024)

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

where UR represents the number of use-reports for each use category and N is the total number of informants. This approach enabled us to identify species that hold not only therapeutic value but also a culturally embedded role in local medical traditions.

Additionally, we computed the fidelity level (FL) to evaluate the uniqueness of plant utilization for specified applications (Jena 2025). We utilized the formula.

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

Ethical Considerations

Prior informed consent was obtained from all participants. The study respected local knowledge systems and traditional practices, ensuring confidentiality and acknowledgement of community contributions.

Compliance with the Nagoya Protocol and Access and Benefit Sharing (ABS)

This research complies with the provisions of the Convention on Biological Diversity (CBD, 1992) and the Nagoya Protocol on Access to Genetic Resources and the Fair and Equitable Sharing of Benefits Arising from their Utilisation (2014). Prior Informed Consent (PIC) was obtained from all participating community members and traditional healers before collecting ethnobotanical data.

Access to traditional knowledge associated with biological resources was conducted in alignment with the Biological Diversity Act (2002) and Biological Diversity Rules (2004) under the supervision of the National Biodiversity Authority (NBA), Government of India. No collection of genetic material for commercial or bioprospecting purposes was undertaken in this study; hence, an Internationally Recognised Certificate of Compliance (IRCC) was not applicable.

The research was performed purely for academic and conservation purposes. The authors affirm their commitment to establish Mutually Agreed Terms (MAT) and follow Access and Benefit Sharing (ABS) procedures with the relevant communities and authorities should future research involve bioactive compound isolation, commercialization, or technology transfer. Traditional knowledge holders and local communities are duly acknowledged as custodians of this heritage.

Results

The socio-demographics profile of the respondents

The socio-demographic survey of 90 participants across Khordha district revealed several important trends. Among the different localities, Khordha Town recorded the highest representation with 18 participants (20%), suggesting greater engagement in ethnobotanical practices in urban centres, possibly due to better access to markets, educational institutions, and diverse plant resources. Jatni followed with 14 participants (15.56%), while Balugaon (12 participants, 13.33%) and Banapur (10 participants, 11.11%) contributed moderately. Smaller contributions came from Nirakarpur (8 participants, 8.89%), Begunia (9 participants, 10%), Chandaka (10 participants, 11.11%), and Balianta (9 participants, 10%), indicating that ethnobotanical knowledge is distributed across both urban and rural settlements, although slightly higher in urbanised areas where interaction with multiple communities may enhance awareness. Figure 2 represents different localities of the study area and demonstrates the number of respondents.

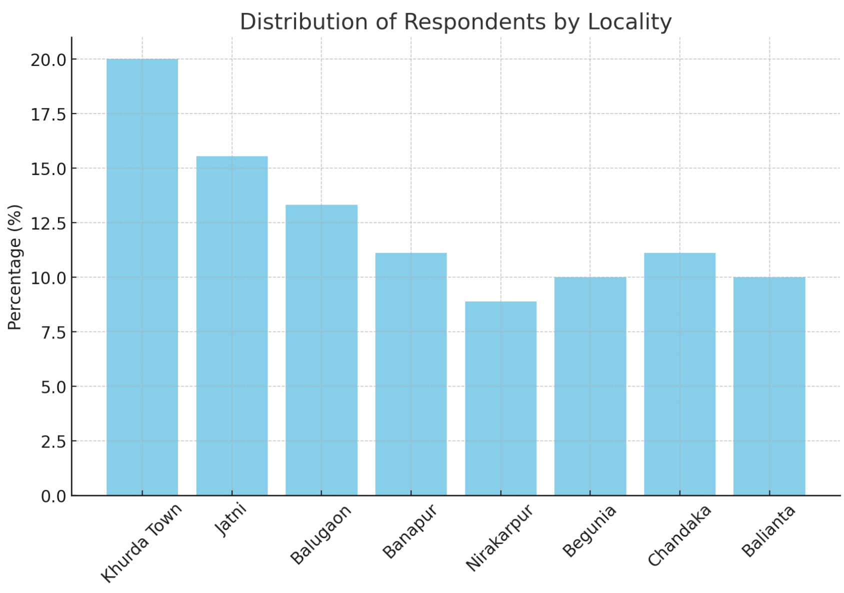

Figure 2. Distribution of the respondents by different localities of the study area.

The gender distribution was relatively balanced, with 46 males (51.11%) and 44 females (48.89%), reflecting that both men and women are actively involved in the collection, preparation, and utilisation of medicinal plants, although specific roles may vary according to traditional practices. In terms of occupation, small farmers and cultivators formed the largest group at 24.44%, followed by women self-help group members engaged in selling herbal products and vegetables at 23.33%, and traditional herbal practitioners at 21.11%, highlighting the significant role of local communities in sustaining ethnobotanical knowledge. Fisherfolk contributed 12.22%, and local herbal vendors or plant sellers accounted for 18.89%. Regarding age distribution, most participants were between 40 and 60 years (34.44%), followed by 60-80 years (30%), below 40 years (23.33%), and above 80 years (12.22%), indicating that middle-aged and elderly individuals are primary custodians of traditional knowledge. Education levels showed that the majority had primary education (32.22%), followed by secondary/high school (27.78%), no formal education (23.33%), and vocational/college-level education (16.67%), suggesting that ethnobotanical knowledge is maintained across varying educational backgrounds. Table 1 summarizes the socio-demographic characteristics of the respondents, including locality, gender, occupation, age group, and education level.

Table 1. Socio-demographic profile of respondents

Socio-Demographic Variables	**Parameters**	**Sample Number (n=90)**	**Percentage (%)**
Locality	Khordha Town	18	20.00
	Jatni	14	15.56
	Balugaon	12	13.33
	Banapur	10	11.11
	Nirakarpur	8	8.89
	Begunia	9	10.00
	Chandaka	10	11.11
	Balianta	9	10.00
Gender	Male	46	51.11
	Female	44	48.89
Occupation	Traditional herbal practitioners	19	21.11
	Small farmers/cultivators	22	24.44
	Fisherfolk (seasonal / reservoir-based)	11	12.22
	Women SHG members (selling herbal products/vegetables)	21	23.33
	Local herbal vendors / plant sellers	17	18.89
Age Group	Below 40 years	21	23.33
	40-60 years	31	34.44
	60-80 years	27	30.00
	Above 80 years	11	12.22
Education Level	No formal education	21	23.33
	Primary education	29	32.22
	Secondary / High school	25	27.78
	Vocational / College-level	15	16.67

Several species, such as *Azadirachta indica* (Neem), *Curcuma longa* (Haldi), *Zingiber officinale* (Ada), *Ocimum sanctum* (Tulsi), and *Tinospora cordifolia* (Guluchi) were widely utilised due to their antimicrobial, antioxidant, and anti-inflammatory properties. Plants were sourced from a variety of habitats, including homestead gardens, roadside areas, forest edges, temple premises, and wetlands, indicating the integration of both wild and cultivated species in daily ethnomedicinal practices. The survey revealed that leaves were the most commonly used plant part, followed by roots, fruits, rhizomes, and whole plants, reflecting ease of availability and preparation. Fig.4 mentions different plant parts having medicinal properties according to the respondent. Consumable forms varied from fresh leaf paste, decoctions, and infusions to powders, juices, and traditional preparations like chutneys and Triphala mixtures. Collection methods largely involved hand plucking, fruit or pod collection, rhizome digging, and root extraction, with several species being harvested both from wild habitats and cultivation, while others were exclusively cultivated (*Curcuma longa*, *Zingiber officinale*, *Allium sativum*, *Ocimum gratissimum*). Seasonal availability was also noted, with some species accessible throughout the year (Azadirachta indica, Ocimum sanctum, Moringa oleifera), whereas others were season-specific, such as *Withania somnifera*, *Phyllanthus emblica*, and *Terminalia species* during winter, and Cassia fistula and Tamarindus indica in summer.

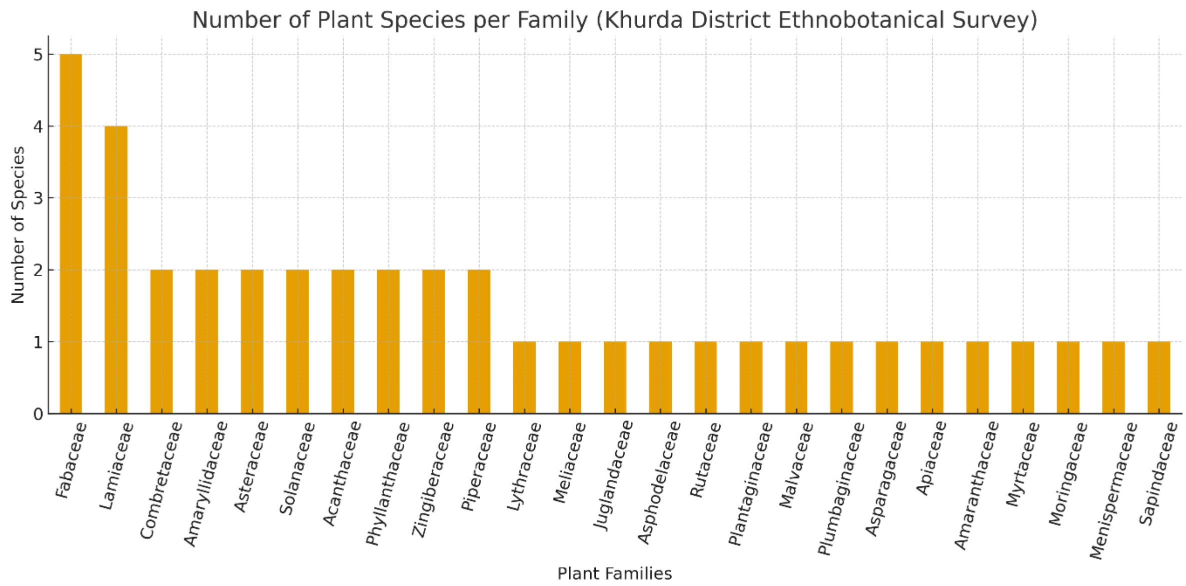

Figure 3. Distribution of the different families of plant species obtained from the study.

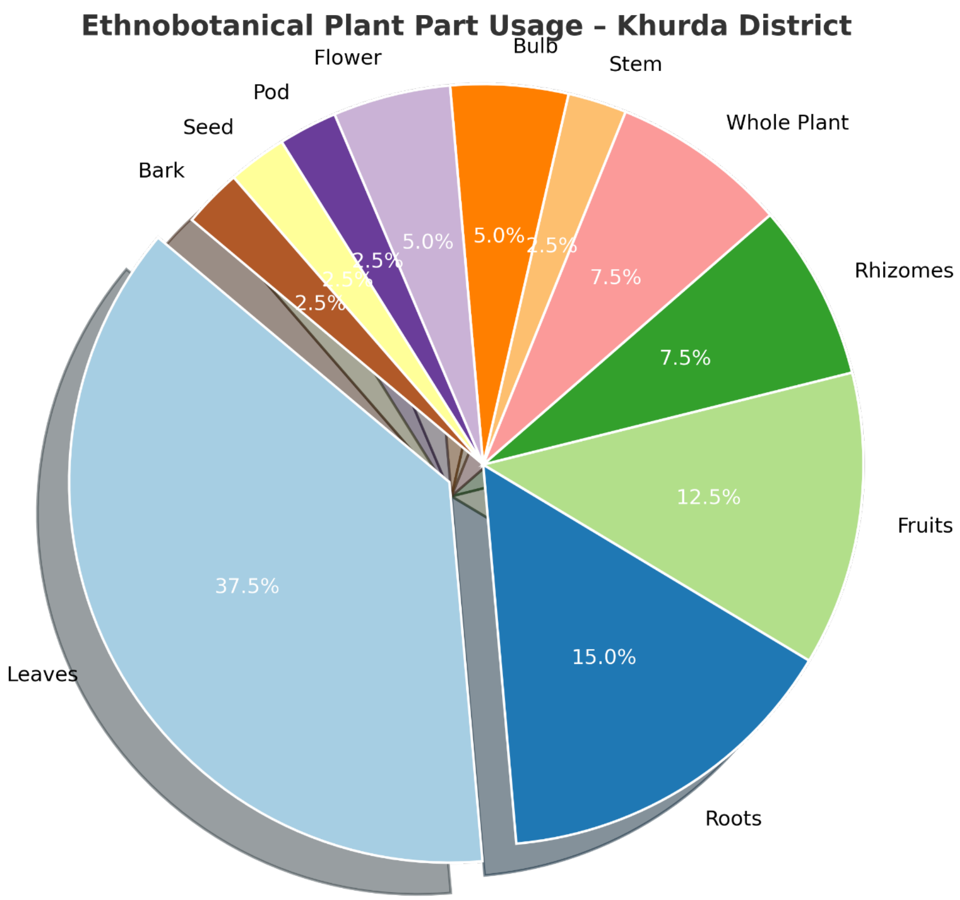

Figure 4. Usage ratio of plant parts reported by the respondents.

Certain culturally significant plants, like Datura metel, were used cautiously due to their toxic nature, illustrating the local knowledge of safe usage. Overall, this inventory underscores the diversity, multi-functional uses, and conservation of medicinal plants in Khordha, highlighting the vital role of both cultivated and wild species in supporting traditional healthcare and community well-being. Table 2 presents the documented medicinal plant species with their botanical names, families, local names, seasonal availability, voucher specimen numbers, habitats, parts used, forms of consumption, collection methods, and growth nature.

Table 2. List of medicinal plant species documented from Khordha district with ethnomedicinal uses and collection details

Family	**Species Name (with Authority)**	**Local Name**	**Season Available**	**Voucher Specimen No.**	**Habitat**	**Part Used**	**Consumable Form**	**Collection Method**	**Nature (Wild/Cultivated)**
Acanthaceae	*Andrographis paniculata* (Burm.f.) Nees	Kalmegh	Monsoon	KH-007	Forest clearings	Whole plant	Decoction	Uprooting whole plant	Wild
Acanthaceae	*Phlogacanthus thyrsiformis* (T.Anderson) J.R.I.Wood & R.M.Barker	Devlata	Monsoon	KH-040	Moist thickets	Leaves	Decoction	Hand plucking	Wild
Amaranthaceae	*Achyranthes aspera* L.	Apamarga	All year	KH-018	Roadside wastelands	Whole plant	Decoction	Uprooting plant	Wild
Amaryllidaceae	*Allium cepa* L.	Piaja	Winter	KH-016	Market / gardens	Bulb	Raw slices, paste	Bulb harvesting	Cultivated
Amaryllidaceae	*Allium sativum* L.	Rasuna	Winter	KH-015	Home gardens	Bulb	Crushed raw, paste	Bulb harvesting	Cultivated
Apiaceae	*Centella asiatica* (L.) Urb.	Thankuni	Monsoon & Post-Monsoon	KH-020	Moist shady areas	Leaves	Fresh leaf juice	Hand plucking	Wild
Asparagaceae	*Asparagus racemosus* Willd.	Satavari	Winter	KH-021	Forest edges	Root tuber	Powder, decoction	Root digging	Wild
Asphodelaceae	*Aloe vera* (L.) Burm.f.	Ghritkumari	All year	KH-023	Home gardens	Leaf gel	Raw gel, juice	Leaf cutting	Cultivated
Asteraceae	*Artemisia indica* Willd.	Nagdauna	Winter	KH-031	Open scrub	Leaves	Decoction	Leaf plucking	Wild
Asteraceae	*Eclipta prostrata* (L.) L.	Bhringraj	Monsoon	KH-025	Moist fields	Whole plant	Paste, juice	Hand plucking	Wild
Combretaceae	*Terminalia bellirica* (Gaertn.) Roxb.	Bahada	Winter	KH-011	Forest	Fruit	Powder, Triphala mix	Fruit collection	Wild
Combretaceae	*Terminalia chebula* Retz.	Harida	Winter	KH-010	Forest	Fruit	Powder, decoction	Fruit collection	Wild
Fabaceae	*Bauhinia variegata* L.	Kanchan	Spring	KH-032	Forest	Flower, Bark	Flower curry, bark decoction	Hand collection	Wild
Fabaceae	*Cassia alata* L.	Dadmardan	Monsoon	KH-033	Moist open fields	Leaves	Leaf paste	Hand plucking	Wild
Fabaceae	*Cassia fistula* L.	Bandara	Summer	KH-022	Forest roadside	Pods	Pulp, decoction	Pod collection	Wild

Fabaceae	*Mimosa pudica* L.	Lajjalu	Monsoon	KH-019	Open field / wastelands	Root, Leaf	Paste, juice	Hand plucking	Wild
Fabaceae	*Tamarindus indica* L.	Tentuli	Summer	KH-036	Village groves	Fruit, Leaf	Pulp, chutney	Pod plucking	Cultivated
Juglandaceae	*Juglans regia* L.	Akhrot	Winter	KH-029	Cultivated orchard	Seed, Bark	Kernel, decoction	Nut collection	Cultivated
Lamiaceae	*Clerodendrum viscosum* Vent.	Bhat	Monsoon	KH-035	Forest fringes	Leaves	Paste, decoction	Hand plucking	Wild
Lamiaceae	*Mentha arvensis* L.	Podina	Winter	KH-028	Home gardens	Leaves	Fresh chutney, tea	Hand plucking	Cultivated
Lamiaceae	*Ocimum gratissimum* L.	Ram Tulsi	All year	KH-037	Home gardens	Leaves	Fresh juice	Hand plucking	Cultivated
Lamiaceae	*Ocimum sanctum* L.	Tulsi	All year	KH-004	Home gardens / Temple premises	Leaves	Fresh leaves, juice	Hand plucking	Cultivated
Lythraceae	*Lawsonia inermis* L.	Mendi	Summer	KH-027	Village backyard	Leaves	Paste	Hand plucking	Cultivated
Malvaceae	*Hibiscus rosa-sinensis* L.	Mandar	All year	KH-024	Home gardens	Flower, Leaf	Flower paste, tea	Hand plucking	Cultivated
Meliaceae	*Azadirachta indica* A.Juss.	Neem	All year	KH-001	Roadside / Village areas	Leaves, Bark	Fresh leaf paste, decoction	Hand plucking	Wild & Cultivated
Menispermaceae	*Tinospora cordifolia* (Willd.) Miers	Guluchi	All year	KH-005	Climber on trees	Stem	Stem decoction	Stem cutting	Wild
Moringaceae	*Moringa oleifera* Lam.	Sajana	All year	KH-008	Village backyards	Leaves, Pod	Leaf curry, soup	Hand plucking	Cultivated
Myrtaceae	*Syzygium cumini* (L.) Skeels	Jamukoli	Summer	KH-012	Forest / roadsides	Seed, Bark	Seed powder, bark decoction	Fruit plucking	Wild & Cultivated
Phyllanthaceae	*Phyllanthus emblica* L. (= Emblica officinalis Gaertn.)	Aonla	Winter	KH-009	Forest edges / plantations	Fruit	Fresh fruit, powder	Hand picking	Wild & Cultivated
Phyllanthaceae	*Phyllanthus niruri* L.	Bhumiamla	Monsoon	KH-026	Roadside, open field	Whole plant	Fresh juice	Hand plucking	Wild
Piperaceae	*Piper longum* L.	Pippali	Winter	KH-014	Forest edges	Fruit, Root	Powder, decoction	Fruit plucking	Wild

Piperaceae	*Piper nigrum* L.	Golmorich	Winter	KH-013	Backyard climber	Fruit	Dried spice powder	Fruit collection	Cultivated
Plantaginaceae	*Scoparia dulcis* L.	Mithi booti	Monsoon	KH-034	Open scrubland	Whole plant	Decoction	Uprooting	Wild
Plumbaginaceae	*Plumbago zeylanica* L.	Chitrak	Winter	KH-017	Forest clearings	Root	Root paste	Root digging	Wild
Rutaceae	*Murraya koenigii* (L.) Spreng.	Karipatta	All year	KH-030	Home gardens	Leaves	Fresh leaves in food	Hand plucking	Cultivated
Sapindaceae	*Filicium decipiens* (Wight) Thwaites	Fern Tree	All year	KH-039	Planted avenues	Leaves (research use)	Crude extract	Leaf collection	Cultivated
Solanaceae	*Datura metel* L.	Dhutura	All year	KH-038	Roadside wastelands	Leaf, Seed (controlled)	Paste, smoke (traditional)	Fruit plucking	Wild (Caution)
Solanaceae	*Withania somnifera* (L.) Dunal	Ashwagandha	Winter	KH-006	Forest edges / open field	Root	Root powder	Root digging	Wild & Cultivated
Zingiberaceae	*Curcuma longa* L.	Haldi	Monsoon & Post-Monsoon	KH-002	Homestead gardens	Rhizome	Powder, paste	Rhizome digging	Cultivated
Zingiberaceae	*Zingiber officinale* Roscoe	Ada	Monsoon & Post-Monsoon	KH-003	Home gardens	Rhizome	Fresh juice, decoction	Rhizome digging	Cultivated

Pharmacological and Ethnobotanical Insights of Key Medicinal Plants

The ethnobotanical survey of Khordha district revealed 40 medicinal plant species with diverse therapeutic activities, bioactive constituents, and traditional preparation methods, reflecting the deep pharmacological knowledge embedded in local communities. *Azadirachta indica* (Neem) and *Curcuma longa* (Haldi) were among the most widely used plants, exhibiting antimicrobial, antioxidant, anti-inflammatory, and analgesic properties, largely attributed to azadirachtin, nimbidin, and curcumin, respectively. These bioactive compounds modulate inflammatory pathways (↓TNF-α, ↓IL-1β, COX/LOX inhibition) and scavenge free radicals, with common preparations including leaf pastes, rhizome decoctions, and oil macerations.

Rhizomatous species like *Zingiber officinale* (Ginger) and aromatic herbs such as *Ocimum sanctum* (Tulsi) and *Ocimum gratissimum* (Ram Tulsi) displayed anti-inflammatory, antimicrobial, and antioxidant activities mediated via COX/LOX inhibition, NF-κB modulation, and reactive oxygen species scavenging, often consumed as fresh juices, decoctions, or essential oils. Immunomodulatory plants like *Tinospora cordifolia* (Guduchi) and adaptogens like *Withania somnifera* (Ashwagandha) were traditionally used in decoctions or powders to enhance immunity, reduce inflammation, and regulate oxidative stress.

Fruits such as *Phyllanthus emblica* (Aonla), *Terminalia chebula* (Harida), and *Terminalia bellirica* (Bahada) were rich in vitamin C, tannins, and polyphenols, conferring antioxidant and antimicrobial effects, often incorporated into powders, Triphala formulations, or fresh juices. Leafy greens and herbs, including *Eclipta prostrata*, Centella asiatica, and *Moringa oleifera*, served both internal and topical roles, enhancing wound healing, antioxidant defences, and anti-inflammatory responses.
Spices and bulbs like Allium sativum, Allium cepa, Piper nigrum, and Piper longum provided antimicrobial and anti-inflammatory benefits through sulfur compounds, piperine, and related phytochemicals. Some toxic species, such as Datura metel, were traditionally used topically with caution due to tropane alkaloids. Other species, including *Filicium decipiens* and *Phlogacanthus thyrsiformis*, had limited phytochemical data but were employed in folk medicine for anti-inflammatory or antimicrobial purposes. Table 3 summarises the ethnopharmacological relevance of selected medicinal plant species, highlighting their reported biological activities, principal bioactive compounds, proposed molecular or pharmacological mechanisms, common dosage forms, and traditional methods of preparation.

Use Value, Relative Frequency of Citation, and Cultural Importance of Medicinal Plants

The ethnobotanical assessment of 40 medicinal plant species in Khordha district using participant responses (IP), informant reports (IR), use reports (UR), relative frequency of citation (RFC), and cultural importance (CI) revealed significant trends in local knowledge and utilisation patterns. *Filicium decipiens* exhibited the highest RFC (0.988) and CI (0.978), indicating its wide recognition and cultural relevance among the community, while other highly cited species included *Achyranthes aspera* and Cassia fistula (RFC = 0.989), reflecting their prominence in traditional medicine practices. Plants such as *Azadirachta indica*, *Withania somnifera,* and *Terminalia chebula* also showed high RFC values (0.956-0.967), demonstrating their frequent use for antimicrobial, anti-inflammatory, and antioxidant purposes.

Several species displayed a discrepancy between use reports and cultural importance, suggesting that while some plants are widely known (*Allium cepa*, CI = 1.056; *Zingiber officinale*, CI = 1.056), their actual usage may vary depending on accessibility, preparation methods, and seasonal availability. Commonly used and culturally significant plants like *Tinospora cordifolia* (CI = 0.833), *Phyllanthus emblica* (CI = 0.900), and *Murraya koenigii* (CI = 0.911) underscore the integration of bioactive species in daily health practices.

Toxic or carefully used species, such as Datura metel (RFC = 0.822; CI = 0.767), were cited less frequently, reflecting traditional knowledge of caution in their application. Overall, the data highlight that medicinal plants with high RFC and CI values, including *Azadirachta indica*, *Curcuma longa*, *Withania somnifera*, and *Filicium decipiens*, form the core of ethnomedicinal practices in the district. These findings emphasise the interplay between community recognition, actual usage, and cultural importance, offering a quantitative basis for selecting species for further pharmacological validation and conservation priorities. Table 4 represents the information about different quantitative ethnobotanical indices of medicinal plant species documented in the study.

Table 3. Reported pharmacological activities, key phytoconstituents, and traditional uses of documented medicinal plants from Khordha district.

Species (authority)	Reported activities	Key bioactive constituents (short)	Putative molecular / pharmacological action	Common dosage forms	Typical method of preparation (traditional)	References
Azadirachta indica A.Juss.	Antimicrobial, Antioxidant, Anti-inflammatory, Analgesic	Azadirachtin, nimbidin, nimbin, quercetin, limonoids	Disruption of microbial membranes; inhibition of pro-inflammatory mediators (↓TNF-α, ↓IL-1β), inhibition of COX/LOX pathways; free-radical scavenging.	Leaf paste, decoction, oil, ethanolic extract	Fresh leaf paste for topical wounds; aqueous decoction; oil maceration	Sarkar *et al.* 2021
Curcuma longa L.	Anti-inflammatory, Antioxidant, Analgesic, Antimicrobial (adjunct)	Curcumin (di-demethoxycurcumin etc.)	Inhibition of NF-κB activation, ↓COX-2 and ↓iNOS expression, antioxidant ROS scavenging and Nrf2 activation; membrane-active against some microbes.	Powder, tincture, ethanolic/aqueous extract, capsules (standardized curcuminoids)	Rhizome decoction, powdered rhizome mixed in food; alcoholic extraction for concentrated curcuminoids	Jyotirmayee & Mahalik , 2022
Zingiber officinale Roscoe	Anti-inflammatory, Analgesic, Antimicrobial, Antioxidant	Gingerols, shogaols, zingerone	Inhibition of COX/LOX enzymes, suppression of pro-inflammatory cytokines; TRPV1 modulation (analgesia); antimicrobial membrane effects.	Fresh juice, decoction, powder, essential oil	Fresh rhizome crushed for juice/tea; decoction or poultice	Xing *et al.* 2024
Ocimum sanctum L.	Antimicrobial, Antioxidant, Anti-inflammatory, Analgesic	Eugenol, ursolic acid, rosmarinic acid, apigenin	Eugenol: membrane disruption of microbes; ↓NF-κB signaling, ↓pro-inflammatory cytokines; antioxidant phenolics scavenge ROS.	Fresh leaf juice, decoction, essential oil	Fresh leaf infusion or chewing; steam distillation for oil	Sukhija *et al.* 2024
Tinospora cordifolia (Willd.) Miers	Immunomodulatory, Antioxidant, Anti-inflammatory, Antimicrobial	Berberine-type alkaloids, tinosporaside, diterpenoid lactones	Modulation of innate/adaptive immunity (macrophage activation), inhibition of cytokine release (↓TNF-α), antioxidant enzyme upregulation.	Decoction (stem), concentrated extracts	Stem bark/stem decoction; dried stem powder	Chaudhary *et al.* 2024
Withania somnifera (L.) Dunal	Anti-inflammatory, Antioxidant, Analgesic, Immunomodulatory	Withanolides (withaferin A), sitoindosides	Inhibition of NF-κB; HSP modulation; antioxidant enzyme induction; withaferin A modulates inflammatory signaling and apoptotic pathways.	Root powder (churna), tincture, capsules	Dried root powder in milk; decoction or alcoholic extractor	Ramli *et al.* 2023
Andrographis paniculata (Burm.f.) Nees	Antimicrobial, Anti-inflammatory, Analgesic	Andrographolide, diterpenes	Inhibits NF-κB and MAPK signaling → ↓pro-inflammatory cytokines; reported bacteriostatic effects via cell-wall target modulation.	Aqueous decoction, ethanol extract, tablets	Whole-plant decoction or ethanolic extract concentrated	Hossain *et al.* 2021

Moringa oleifera Lam.	Antioxidant, Antimicrobial, Anti-inflammatory	Quercetin, kaempferol, glucosinolates, isothiocyanates	Antioxidant flavonoids scavenge ROS; glucosinolates/isothiocyanates show antimicrobial activity; modulation of inflammatory mediators.	Leaf powder, decoction, oil	Sun-dried leaf powder (leaf tea), leaf paste	Shah & Oza , 2022
Phyllanthus emblica L. (= Emblica officinalis Gaertn.)	Antioxidant, Antimicrobial, Anti-inflammatory	Ascorbic acid, tannins (gallic/ellagic acids), flavonoids	High vitamin C + polyphenols → potent antioxidant activity; tannins show antimicrobial effects via protein binding; ↓inflammatory mediators.	Fruit juice, powder, decoction	Fresh fruit juice, dried fruit powder, decoction	Kapoor *et al.* 2023
Terminalia chebula Retz.	Antimicrobial, Antioxidant, Anti-inflammatory	Chebulagic acid, chebulinic acid, tannins	Tannins bind microbial proteins (antimicrobial); polyphenols scavenge ROS; inhibition of inflammatory enzymes (COX/LOX) reported.	Powder, decoction, Triphala formulations	Fruit drying and powdering; decoction	Wang *et al.* 2024
Terminalia bellirica (Gaertn.) Roxb.	Antioxidant, Antimicrobial, Anti-inflammatory	Gallic acid, ellagic acid, tannins	Tannins and phenolics contribute to antimicrobial action and antioxidant ROS scavenging; modulation of inflammatory mediators.	Powder, decoction, Triphala	Dried fruit powder; decoction	Tiwana *et al.* 2024
Syzygium cumini (L.) Skeels	Antioxidant, Antimicrobial	Anthocyanins, ellagic acid, flavonoids	Anthocyanins act as antioxidants; polyphenols show bacteriostatic effects; reported inhibition of pro-inflammatory pathways.	Fruit extract, seed powder, decoction	Fresh fruit/seed powder, decoction	Hassanin *et al.* 2023
Piper nigrum L.	Antimicrobial, Anti-inflammatory (adjunct), Analgesic (minor)	Piperine, essential oils	Piperine enhances bioavailability of other compounds; antimicrobial via membrane disruption; inhibition of inflammatory mediators in some models.	Dried spice, ethanolic extract, oil	Drying and grinding of fruits; alcoholic or oil extraction	Takooree *et al.* 2019
Piper longum L.	Antimicrobial, Analgesic, Anti-inflammatory	Piperlongumine, piperine	Piperlongumine modulates NF-κB and oxidative stress pathways; antimicrobial activity against certain pathogens.	Powder, decoction, tincture	Fruit powder; decoction or alcoholic extract	Biswas *et al.* 2022
Allium sativum L.	Antimicrobial, Antioxidant, Anti-inflammatory, Analgesic (traditional)	Allicin (thiosulfinates), ajoene, flavonoids	Allicin reacts with thiol groups in microbial enzymes → antimicrobial; antioxidant effects via sulfur compounds; modulation of inflammatory cytokines.	Raw crushed bulb, oil, extract	Fresh crushing/crushing to release allicin; oil maceration	Oh 2022

Allium cepa L.	Antimicrobial, Antioxidant, Anti-inflammatory	Quercetin, sulfur compounds	Quercetin acts as antioxidant and anti-inflammatory (↓COX); sulfur compounds show antimicrobial action.	Raw slices, paste, decoction	Crushing/slicing of bulb; heating lowers allicin but retains flavonoids	Omoboyede *et al.* 2024
Plumbago zeylanica L.	Antimicrobial, Analgesic, Anti-inflammatory	Plumbagin (naphthoquinone)	Plumbagin generates ROS against microbes; modulates NF-κB and induces apoptosis in some models; can be cytotoxic — used carefully.	Root paste, ethanolic extract	Root powder or paste; alcoholic extraction for concentrated plumbagin	Nandi *et al.* 2025
Achyranthes aspera L.	Anti-inflammatory, Analgesic, Antimicrobial	Saponins, alkaloids, flavonoids	Saponins and flavonoids reduce pro-inflammatory mediators; membrane-active antimicrobial effects reported.	Decoction, poultice, paste	Whole-plant decoction or topical paste	Huq *et al.* 2024
Mimosa pudica L.	Anti-inflammatory, Antimicrobial, Analgesic	Tannins, flavonoids, alkaloids	Tannins: protein precipitation (antimicrobial); flavonoids: antioxidant and inhibition of inflammatory enzymes.	Leaf decoction, poultice	Leaf decoction or fresh leaf paste	Kumar 2021
Centella asiatica (L.) Urb.	Anti-inflammatory, Antioxidant, Analgesic (wound healing)	Asiaticoside, madecassoside, triterpenoids	Promotes collagen synthesis (wound healing), modulates inflammatory cytokines, antioxidant effects.	Leaf extract, topical ointment, decoction	Fresh leaf paste for topical use; decoction or alcoholic extract	Fan & Yin, 2021
Asparagus racemosus Willd.	Antioxidant, Anti-inflammatory, Analgesic (traditional)	Steroidal saponins (shatavarin), flavonoids	Saponins modulate immune response; antioxidant scavenging; reported inhibition of inflammatory mediators.	Root powder (churna), decoction, tonic	Dried root powder, decoction, taken with milk	Kumar *et al.* 2023
Cassia fistula L.	Antimicrobial, Anti-inflammatory	Anthraquinones, flavonoids, sennosides	Flavonoids and anthraquinones impart antioxidant and antimicrobial effects; modulation of inflammatory markers reported.	Pod pulp decoction, paste	Pod pulp decoction; topical poultice	Kanwal *et al.* 2022
Aloe vera (L.) Burm.f.	Anti-inflammatory, Antimicrobial, Analgesic, Antioxidant, Wound-healing	Acemannan (polysaccharide), aloins, anthraquinones	Polysaccharides stimulate fibroblast activity; anti-inflammatory via ↓COX and immunomodulation; antimicrobial glycosides active topically.	Leaf gel, topical gel, juice	Fresh leaf gel extracted and applied topically; gel preparations	Wu *et al.* 2025
Hibiscus rosa-sinensis L.	Antioxidant, Anti-inflammatory (traditional)	Flavonoids, anthocyanins	Antioxidant flavonoids scavenge ROS; some anti-inflammatory enzyme inhibition reported.	Flower decoction, paste, oil	Flower decoction/infusion; poultice	Amtaghri *et al.* 2024

Eclipta prostrata (L.) L.	Antioxidant, Antimicrobial, Anti-inflammatory	Wedelolactone, demethylwedelolactone, flavonoids	Wedelolactone modulates inflammatory signaling (NF-κB), shows antimicrobial and antioxidant activity.	Leaf paste, decoction, topical oil	Leaf paste or decoction for hair/scalp and topical uses	Le *et al.* 2021
Phyllanthus niruri L.	Antioxidant, Antimicrobial, Anti-inflammatory	Lignans, flavonoids (phyllanthin), tannins	Antiviral/antimicrobial tannin activity; antioxidant polyphenols; modulation of inflammatory cytokines reported.	Aqueous decoction, extract	Whole-plant decoction or infusion	Lee *et al.* 2016
Lawsonia inermis L.	Antimicrobial, Anti-inflammatory	Lawsone (henna pigment), tannins	Lawsone binds microbial proteins; antiseptic activity topically; tannins impart astringent, anti-inflammatory actions.	Leaf paste, topical poultice, dye	Fresh leaf paste applied topically (henna)	Mustapha *et al.* 2024
Mentha arvensis L.	Antimicrobial, Analgesic (topical cooling), Antioxidant	Menthol, menthone, flavonoids	Menthol acts on TRP channels (analgesia/cooling), essential oils disrupt microbial membranes; antioxidant flavonoids present.	Leaf infusion (tea), essential oil, topical rub	Leaf infusion, steam distillation for oil; fresh leaf poultice	Wei *et al.* 2023
Juglans regia L.	Antioxidant, Antimicrobial (some parts)	Juglone, tannins, phenolics	Juglone (naphthoquinone) shows antimicrobial activity via redox cycling; tannins: protein binding; antioxidant phenolics.	Kernel oil, decoction, topical paste	Kernel oil extraction, leaf/ bark decoction	Bhat *et al.* 2023
Murraya koenigii (L.) Spreng.	Antioxidant, Antimicrobial, Anti-inflammatory	Carbazole alkaloids (mahanine), flavonoids	Flavonoids and alkaloids scavenge ROS and modulate inflammatory cytokines; antimicrobial against some bacterial strains.	Fresh leaves (culinary), decoction, extract	Fresh leaf paste or infusion; leaf extraction	El-Shiekh *et al.* 2024
Artemisia indica Willd.	Antimicrobial, Anti-inflammatory, Antioxidant	Artemisinin-type terpenes (in some spp.), flavonoids	Terpenoids and flavonoids show anti-inflammatory and antimicrobial effects via multiple pathways (enzyme inhibition, membrane effects).	Decoction, topical poultice, essential oil	Leaf decoction; steam distillation for oils	Pirintsos al., 2022
Bauhinia variegata L.	Anti-inflammatory, Antioxidant	Flavonoids, tannins	Flavonoids scavenge ROS and inhibit pro-inflammatory enzymes; tannins show antimicrobial/ astringent effects.	Flower decoction, bark decoction	Flower/bark decoction or paste	Zhang *et al.* 2022
Cassia alata L.	Antifungal/Antimicrobial, Anti-inflammatory	Anthraquinones, flavonoids	Anthraquinones exert antifungal/antimicrobial effects;	Leaf paste, topical application	Fresh leaf paste applied to fungal lesions; decoction for baths	Saptarini *et al.* 2024

			flavonoids show antioxidant and anti-inflammatory effects.			
Scoparia dulcis L.	Analgesic, Anti-inflammatory, Antioxidant	Scoparic acids, flavonoids	Inhibition of prostaglandin synthesis; antioxidant flavonoids scavenge ROS.	Decoction, juice, poultice	Whole-plant decoction or juice; topical poultice	Jiang *et al.* 2022
Clerodendrum viscosum Vent.	Anti-inflammatory, Antimicrobial	Triterpenoids, flavonoids	Triterpenoids modulate inflammatory cytokines; flavonoids provide antioxidant/antimicrobial actions.	Leaf paste, decoction	Leaf paste/topical; decoction for internal use	Hossain *et al.* 2025
Tamarindus indica L.	Antioxidant, Antimicrobial	Tannins, tartaric acid, polyphenols	Tannins bind microbial proteins (antimicrobial); polyphenols scavenge ROS; mild anti-inflammatory effects reported.	Fruit pulp, decoction, chutney	Fruit pulp extraction; decoction or culinary preparations	Medeiros *et al.* 2021
Ocimum gratissimum L.	Antimicrobial, Antioxidant, Anti-inflammatory	Eugenol, thymol, flavonoids	Eugenol/thymol disrupt microbial membranes; phenolics inhibit inflammatory pathways and scavenge ROS.	Leaf infusion, essential oil, decoction	Fresh leaf infusion; steam distillation for oil	Ugbogu *et al.* 2021
Datura metel L.	Analgesic (traditional), Anti-inflammatory (traditional) — TOXIC	Tropane alkaloids (scopolamine, hyoscyamine)	Tropane alkaloids are anticholinergic (central/peripheral): analgesic/sedative effects but narrow therapeutic index and serious toxicity. Use with extreme caution.	Topical poultice (traditional), not recommended internally without strict control	Traditional topical pastes of leaves/seed; high risk of poisoning if ingested	Sharma *et al.* 2021
Filicium decipiens (Wight) Thwaites	Antimicrobial (reports limited), Antioxidant (limited)	Flavonoids, phenolics (limited phytochemical data)	Proposed antioxidant/antimicrobial via polyphenols; specific mechanisms are incompletely characterized in literature.	Leaf extract (research), topical preparations (limited)	Leaf extraction (ethanolic/aqueous) in research settings	Basarikatti *et al.* 2020
Phlogacanthus thyrsiformis (T.Anderson) J.R.I.Wood & R.M.Barker	Anti-inflammatory, Analgesic, Antimicrobial (reported ethnobotany)	Iridoids, flavonoids, phenolics (reported)	Flavonoid/iridoid modulation of inflammatory cytokines; antioxidant activity reported — molecular mechanisms incompletely defined.	Leaf decoction, poultice	Leaf decoction or paste for topical/internal use in folk medicine	Devi *et al.* 2024

Table 4: Quantitative ethnobotanical indices of medicinal plant species documented in the study.

Species Name (with Authority)	**IP (participant)**	**IR (response)**	**UR**	**RFC**	**CI**
Azadirachta indica A.Juss.	87	85	85	0.967	0.944
Curcuma longa L.	85	81	84	0.944	0.933
Zingiber officinale Roscoe	84	80	95	0.933	1.056
Ocimum sanctum L.	84	75	84	0.933	0.933
Tinospora cordifolia (Willd.) Miers	87	83	75	0.967	0.833
Withania somnifera (L.) Dunal	86	84	86	0.956	0.956
Andrographis paniculata (Burm.f.) Nees	75	71	75	0.833	0.833
Moringa oleifera Lam.	82	76	76	0.911	0.844
Phyllanthus emblica L. (= Emblica officinalis Gaertn.)	86	80	81	0.956	0.900
Terminalia chebula Retz.	87	85	82	0.967	0.911
Terminalia bellirica (Gaertn.) Roxb.	81	80	84	0.900	0.933
Syzygium cumini (L.) Skeels	77	75	87	0.856	0.967
Piper nigrum L.	75	71	76	0.833	0.844
Piper longum L.	79	76	71	0.878	0.789
Allium sativum L.	74	72	82	0.822	0.911
Allium cepa L.	71	70	95	0.789	1.056
Plumbago zeylanica L.	85	82	86	0.944	0.956
Achyranthes aspera L.	89	86	75	0.989	0.833
Mimosa pudica L.	84	81	74	0.933	0.822
Centella asiatica (L.) Urb.	81	76	72	0.900	0.800
Asparagus racemosus Willd.	83	80	76	0.922	0.844
Cassia fistula L.	89	84	78	0.989	0.867
Aloe vera (L.) Burm.f.	84	82	74	0.933	0.822
Hibiscus rosa-sinensis L.	75	71	70	0.833	0.778
Eclipta prostrata (L.) L.	77	75	74	0.856	0.822
Phyllanthus niruri L.	79	74	72	0.878	0.800
Lawsonia inermis L.	72	70	69	0.800	0.767
Mentha arvensis L.	81	76	74	0.900	0.822
Juglans regia L.	70	69	78	0.778	0.867
Murraya koenigii (L.) Spreng.	80	76	82	0.889	0.911
Artemisia indica Willd.	76	72	80	0.844	0.889
Bauhinia variegata L.	82	80	84	0.911	0.933
Cassia alata L.	81	79	75	0.900	0.833
Scoparia dulcis L.	80	78	79	0.889	0.878
Clerodendrum viscosum Vent.	75	72	71	0.833	0.789
Tamarindus indica L.	79	75	72	0.878	0.800
Ocimum gratissimum L.	78	74	78	0.867	0.867
Datura metel L.	74	70	69	0.822	0.767
Filicium decipiens (Wight) Thwaites	89	87	92	0.988	0.978
Phlogacanthus thyrsiformis (T.Anderson) J.R.I.Wood & R.M.Barker	71	69	74	0.789	0.822

Top-Performing Medicinal Plants with High Pharmacological Potential

The data reveal several medicinal plants with consistently high pharmacological potential across multiple activities. Cassia fistula stands out with exceptionally high values, showing 98.89% FL in both anti-inflammatory and antioxidant activities, underscoring its dual therapeutic significance. Similarly, Achyranthes aspera also demonstrated 98.89% FL for antioxidant activity, placing it among the most potent candidates for oxidative stress-related disorders. Among widely studied adaptogens, *Tinospora cordifolia* and *Azadirachta indica* exhibited 96.67% FL for both anti-inflammatory and antimicrobial activities, reflecting their broad-spectrum efficacy. Classic Ayurvedic rejuvenators such as *Terminalia chebula* and *Phyllanthus emblica* showed high values (95-96.67%) across anti-inflammatory and antioxidant categories, strengthening their traditional roles in Rasayana therapy. *Withania somnifera*, another cornerstone medicinal plant, recorded 95.56% FL in both anti-inflammatory and analgesic activities, highlighting its versatility in pain and inflammation management. Moreover, plants like *Curcuma longa* and *Zingiber officinale* consistently displayed values above 93% across anti-inflammatory, antimicrobial, antioxidant, and analgesic categories, validating their polypharmacological utility. Collectively, these findings emphasise a cluster of highly effective botanicals—particularly *Cassia fistula*, *Achyranthes aspera*, *Tinospora cordifolia*, *Azadirachta indica*, *Terminalia chebula*, *Phyllanthus emblica*, and *Withania somnifera*—as strong candidates for integrative therapeutic applications. Table 5 presents the ethnopharmacological relevance of selected medicinal plants, showing the percentage of informants reporting their use for anti-inflammatory, antimicrobial, antioxidant, and analgesic activities. Fig.5 represents the list of plants having FL above 90%.

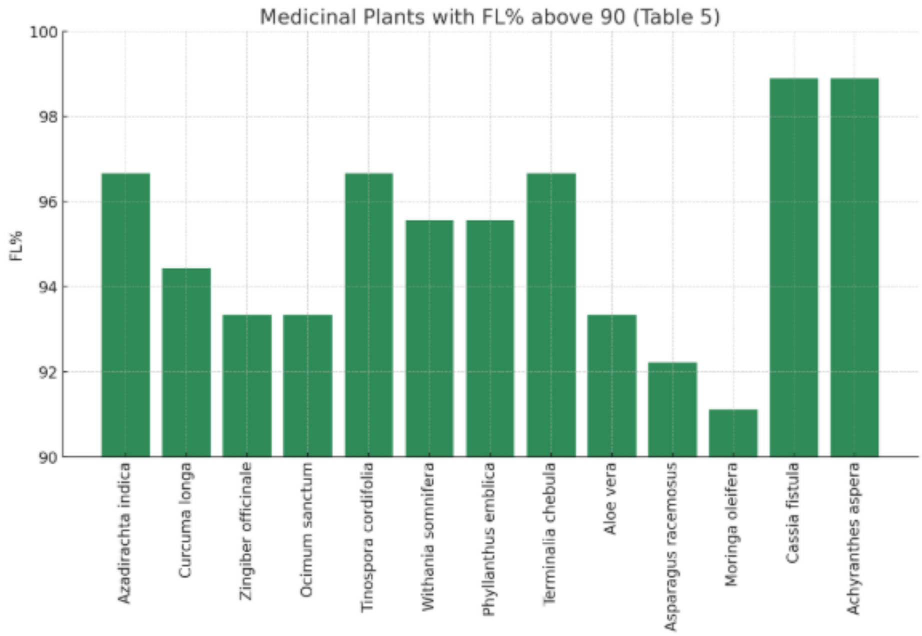

Figure 5. List of plants having FL% more than 90%.

Table 5: Frequency of citation (FL%) of representative medicinal plants for reported pharmacological activities.

Pharmacological Activity	Representative Plants	FL (%)
Anti-inflammatory activity	*Azadirachta indica*	96.67
	Curcuma longa	94.44
	Zingiber officinale	93.33
	Ocimum sanctum	93.33
	Tinospora cordifolia	96.67
	Withania somnifera	95.56
	Phyllanthus emblica	95.56
	Terminalia chebula	96.67
	Aloe vera	93.33
	Asparagus racemosus	92.22
	Moringa oleifera	91.11
	Cassia fistula	98.89
	Centella asiatica	90.00
	Lawsonia inermis	80.00
Antimicrobial activity	*Azadirachta indica*	96.67
	Ocimum sanctum	93.33
	Tinospora cordifolia	96.67
	Allium sativum	82.22
	Allium cepa	78.89
	Zingiber officinale	93.33

	Curcuma longa	94.44
	Syzygium cumini	85.56
	Piper nigrum	83.33
	Piper longum	87.78
	Cassia alata	90.00
	Mimosa pudica	93.33
	Hibiscus rosa-sinensis	83.33
	Datura metel	82.22
	Clerodendrum viscosum	83.33
Antioxidant activity	*Phyllanthus emblica*	95.56
	Terminalia chebula	96.67
	Terminalia bellirica	90.00
	Cassia fistula	98.89
	Achyranthes aspera	98.89
	Moringa oleifera	91.11
	Centella asiatica	90.00
	Bauhinia variegata	91.11
	Ocimum gratissimum	86.67
	Eclipta prostrata	85.56
	Tamarindus indica	87.78
	Juglans regia	77.78
	Syzygium cumini	85.56
	Piper nigrum	83.33
	Allium cepa	78.89
	Allium sativum	82.22
	Hibiscus rosa-sinensis	83.33
Analgesic activity	*Withania somnifera*	95.56
	Curcuma longa	94.44
	Zingiber officinale	93.33
	Ocimum sanctum	93.33
	Datura metel	82.22
	Mentha arvensis	90.00

Discussion

The present study highlights the rich ethnobotanical traditions of Khordha district, demonstrating how rural and tribal communities continue to rely on medicinal plants for managing a diverse range of health conditions. The preference for species such as *Azadirachta indica*, *Curcuma longa*, *Zingiber officinale*, *Ocimum sanctum*, and *Tinospora cordifolia* demonstrates remarkable continuity with ethnomedicinal practices reported across India and beyond (Akhtar & Bashir, 2021). In regions such as Chhattisgarh, Madhya Pradesh, and Jharkhand, these species also occupy dominant positions in local pharmacopoeias, suggesting their widespread recognition as reliable remedies for infections, inflammation, and chronic illnesses. The cross-cultural prominence of these plants highlights the deep pharmacological grounding of traditional knowledge, which has been validated by modern studies demonstrating their antimicrobial, antioxidant, and anti-inflammatory potential (Razzaq *et al.* 2024).

A notable aspect of Khordha ethnomedicine is the integration of antioxidant-rich plants into routine diets. The daily use of *Phyllanthus emblica* (Amla), *Terminalia chebula* (Harida), and *Terminalia bellirica* (Bahada) in preparations like Triphala illustrates the functional overlap between food and medicine. Similar practices are documented in Kerala and Tamil Nadu, where spices and fruits are consumed for both culinary and therapeutic purposes (Haji *et al.* 2023). This convergence reinforces the view that indigenous diets constitute an important preventive healthcare system. Modern biochemical analyses support these practices, showing that polyphenols, flavonoids, and tannins present in these fruits reduce oxidative stress by scavenging free radicals, enhancing endogenous antioxidant enzymes such as superoxide dismutase and catalase, and modulating redox-sensitive signalling pathways (Devi *et al.* 2019).

Polyherbal formulations are another hallmark of Khordha's ethnomedicinal system. Healers frequently combine turmeric, ginger, tulsi, and other herbs for fever, pain, or inflammatory conditions. Comparable practices have been documented in Gujarat, Andhra Pradesh, and even Southeast Asia, where combination therapies are used to enhance efficacy and minimize adverse effects (Pattanayak 2022). Contemporary pharmacology increasingly recognises the scientific validity of these practices. For instance, the co-administration of curcumin and piperine enhances curcumin's bioavailability by inhibiting hepatic glucuronidation, while mixtures of neem and garlic extracts exhibit synergistic antimicrobial activity against resistant pathogens. Such mechanisms affirm the rational basis of traditional formulations (Gajarmal *et al.* 2025).

Mechanistically, many of the key species reported in Khordha act on well-characterised molecular pathways. Curcumin from turmeric inhibits NF-κB activation and downregulates pro-inflammatory cytokines such as TNF-α and IL-1β, providing anti-inflammatory and analgesic effects. Allicin from garlic interacts with thiol groups in microbial enzymes, disrupting membrane integrity and blocking metabolic processes, thereby conferring antimicrobial potency (Fatima *et al.* 2021). Withanolides from *Withania somnifera* modulate NF-κB, induce apoptosis in aberrant cells, and enhance antioxidant defences through Nrf2 activation. Polyphenolic compounds from amla and harida not only neutralise reactive oxygen species but also regulate glucose and lipid metabolism, offering protection against diabetes and cardiovascular disorders. These mechanistic insights strengthen the pharmacological relevance of traditional knowledge and open avenues for new therapeutic discoveries (Patwardhan & Aswar, 2025).

The conservation of medicinal plants emerges as an urgent concern in the Khordha context. Many frequently cited plants, including *Tinospora cordifolia*, *Withania somnifera*, and *Asparagus racemosus*, are collected from forest edges and semi-wild habitats. Overharvesting of roots and bark, in particular, threatens the sustainability of species that regenerate slowly (Shukla *et al.* 2023). Similar concerns are reported from other tribal regions of Odisha, such as Mayurbhanj and Koraput, where demand for high-value medicinal plants is outpacing natural regeneration. Community practices such as maintaining temple groves, cultivating species like tulsi and aloe in home gardens, and protecting certain plants due to ritual significance have historically acted as conservation strategies. However, urbanisation and market pressures are weakening these traditional systems. Integrating modern conservation approaches—such as community seed banks, medicinal plant gardens, and participatory forest management—can help ensure the sustainable availability of these vital resources (Kloos 2023).

Biodiversity preservation is also critical in light of ethnobotanical findings. The ecological mosaic of Khordha—comprising wetlands near Chilika Lake, forest fringes of Chandaka-Dampara, and agrarian plains—supports high medicinal plant diversity. Studies from other biodiverse regions, such as the Western Ghats and northeastern India, demonstrate that ecological diversity directly sustains ethnomedicinal richness (Mykhailenko *et al.* 2025). Loss of habitats through deforestation, agricultural expansion, or climate change threatens not only plant species but also the associated traditional knowledge. The erosion of knowledge is particularly evident among younger generations, who are less engaged in traditional practices. Ethnobotanical documentation, therefore, serves a dual purpose: safeguarding intangible cultural heritage and guiding conservation priorities (Zaman *et al.* 2025).

Comparisons with global studies further validate the findings from Khordha. In African and Southeast Asian ethnomedicine, neem, turmeric, ginger, and amla analogues are widely used for their antimicrobial and antioxidant properties, reflecting the universal pharmacological appeal of these plants (Mir *et al.* 2021). Meanwhile, the careful but continued use of potentially toxic plants such as *Datura metel* mirrors practices in Nagaland, Manipur, and parts of Africa, where community knowledge regulates dosage and application to minimise harm. These parallels suggest that ethnomedicinal systems worldwide converge not only in their selection of bioactive species but also in their strategies for safe and sustainable use (Kaur *et al.* 2022).

Despite the comprehensive ethnobotanical documentation achieved in this study, several limitations should be acknowledged. The findings are based on self-reported data from local informants, which may introduce informant bias due to variations in memory, perception, and individual experience. The absence of in vitro or in vivo pharmacological validation also restricts direct confirmation of the reported bioactivities, while seasonal variation in plant availability could influence the completeness of recorded knowledge (Roy & Pradhan, 2023). Furthermore, although PIC was obtained, no formal access to genetic material was undertaken; thus, IRCC was not applicable at this stage, though future studies will ensure full ABS compliance under India's Biological Diversity Act. A major concern emerging from field interactions is the erosion of traditional knowledge among younger generations. To address this, future initiatives should establish digital herbaria, community-based archives, and intergenerational transfer programs that facilitate the mentorship of youth by traditional healers. Integrating ethnobotanical education into local curricula and promoting participatory conservation projects will further ensure that indigenous plant knowledge is preserved, scientifically validated, and sustainably transmitted to future generations (Radha *et al*. 2023).

The study of Khordha's ethnobotanical findings in relation to other regional reports highlights both shared traditions and distinctive local adaptations. The continuity is evident in the widespread use of multipurpose plants such as neem, turmeric, and amla, while uniqueness arises from the emphasis on locally abundant species like *Filicium decipiens* and *Phlogacanthus thyrsiformis*. The pharmacological mechanisms underlying these practices affirm their scientific credibility, and the cultural embedding of plant use underscores the vital role of tradition in sustaining biodiversity. Furthermore, it is hypothesised that species with high Relative RFC or CI are likely to exhibit strong bioactivity as reported in pharmacological literature, linking ethnobotanical significance with empirical validation. Moving forward, integrating traditional knowledge with conservation biology and pharmacological assessment will be crucial for ensuring the long-term sustainability of medicinal plants and harnessing their potential in future drug discovery.

Future Prospects

Ethnobotanical traditions of Khordha not only safeguard healthcare solutions but also open new frontiers for pharmacological innovation. The unique integration of medicinal plants into daily rituals, diets, and healing practices suggests that their therapeutic relevance extends beyond symptomatic relief to holistic well-being. Future studies should explore the synergistic effects of polyherbal formulations, as many remedies in Khordha combine plants with complementary actions, such as turmeric with ginger or neem with garlic. Advanced tools like metabolomics, network pharmacology, and green nanotechnology could further decode these synergies and enhance their bioavailability for modern use. Community-driven conservation is another pressing area. Establishing ethnobotanical gardens, village nurseries, and digital herbariums could preserve both plant diversity and traditional knowledge, ensuring intergenerational transfer. Moreover, policy frameworks linking local healers with primary healthcare systems can legitimize and strengthen traditional practices while providing economic incentives for sustainable plant cultivation. Future ethnobotanical research should also examine the climate resilience of these plants, as species adapted to Khordha's agro-ecological zones may provide models for sustainable healthcare in changing environments. Thus, the future lies in blending indigenous wisdom with modern science, ensuring that the cultural and therapeutic heritage of Khordha contributes to global health and biodiversity agendas.

Conclusion

The ethnobotanical heritage of Khordha illustrates how cultural traditions and ecological diversity converge to sustain community health. Medicinal plants here are valued not only as therapeutic resources but also as integral elements of a broader cultural ecology—woven into rituals, diets, and local economies. This dual role reflects the sophistication of indigenous healthcare systems, which emphasize accessibility, sustainability, and continuity of knowledge. Importantly, many plants documented in the region exhibit pharmacological relevance across four major domains: antimicrobial species such as neem and garlic that protect against infections; antioxidant-rich fruits like amla and harida that counter oxidative stress and age-related ailments; analgesic herbs including ginger and ashwagandha that alleviate pain and fatigue; and anti-inflammatory agents such as turmeric and cassia fistula that reduce chronic inflammation. Together, these therapeutic actions address some of the most urgent global health concerns while also carrying symbolic and ritual significance in local traditions, underscoring a holistic vision of health. Moving forward, the strength of Khordha's ethnobotany lies in its ability to inspire bioprospecting, integrative medicine, and conservation models that balance cultural values with pharmacological promise. Safeguarding this knowledge is critical not only for local resilience but also for global research, where traditional wisdom provides leads for novel therapeutics and preventive strategies. In conclusion, the ethnobotanical practices of Khordha—anchored in antimicrobial, antioxidant, analgesic, and anti-inflammatory traditions—represent a living heritage that bridges cultural depth with sustainable healthcare futures.

Declarations

List of Abbreviations: UV - Use Value; **UR** - Use Report; **RFC** - Relative Frequency of Citation; **CI** - Cultural Importance Index; **FL** - Fidelity Level; **IP** - Informant Participants; **IR** - Informant Responses; **TNF-α** - Tumor Necrosis Factor alpha; **IL-1β** - Interleukin-1 beta; **COX** - Cyclooxygenase; **LOX** - Lipoxygenase; **NF-κB** - Nuclear Factor kappa-light-chain-enhancer of activated B cells; **iNOS** - Inducible Nitric Oxide Synthase; **ROS** - Reactive Oxygen Species; **Nrf2** - Nuclear factor erythroid 2-related factor 2; **TRPV1** - Transient Receptor Potential Vanilloid 1; **ABS** - Access and Benefit Sharing; **CBD** - Convention on Biological Diversity; **PIC** - Prior Informed Consent; **NBA** - National Biodiversity Authority; **IRCC** - Internationally Recognized Certificate of Compliance; **MAT** - Mutually Agreed Terms

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

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