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Cultural ecology and conservation of traditional beverage practices among selected communities of Assam, Northeast India

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Abstract

Traditional fermented beverages are vital transporters of ecological, spiritual, and cultural knowledge among indigenous communities in Assam, Northeast India. Assam is a bioculturally rich region of Northeast India where traditional fermented beverage practices are still actively maintained and closely linked to local biodiversity and ritual life allowing comparison across distinct cultural groups within a shared ecological landscape. This study explores the cultural ecology of beverage-making practices among the *Bodo*, *Rabha*, and *Ahom* communities through semi-structured interviews, focus group discussions, and participant observation with knowledgeable informants from all three communities. Plant specimens associated with fermented beverage preparation were collected, taxonomically identified, and quantitatively evaluated using indices such as Cultural Key Species Index (CKSI), Use Value (UV), and Fidelity Level (FL%). Qualitative data on rituals, taboos, and knowledge transmission were thematically analyzed to interpret cultural and conservation significance. The study documented 41 plant species across 29 families, with 85% wild-sourced, and identified high cultural importance values (e.g., CKSI up to 0.68 and FL up to 3.78), demonstrating the region's strong integration of indigenous knowledge, conservation ethics, and food traditions. The preparation of beverages such as *Jou*, *Choko*, and *Xajpani* involves diverse plant parts including leaves, roots, and rhizomes used for fermentation, flavor enhancement, preservation, and medicinal benefits. Quantitative indices like the Cultural Keystone Species Index (CKSI) and Fidelity Level (FL) revealed high cultural importance for species such as *Scoparia dulcis* L., *Zingiber officinale* Roscoe, and *Musa paradisiaca* L. The study shows that ritual taboos related to plant collection, brewing, and spiritual offerings promote sustainable harvesting, community-based conservation, with sacred groves serving as socio-ecological sanctuaries where spiritual beliefs support biodiversity preservation, while scientific validation, policy support, and ethical commercialization can enable these traditional beverages to drive cultural revitalization, local livelihoods, and global wellness markets.

Keywords Assam, Biodiversity conservation, Cultural ecology, Ethnic community, Indigenous knowledge, Traditional beverages

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1 Introduction

Traditional ecological knowledge (TEK) forms the foundation of how indigenous communities perceive, manage, and conserve their natural environments. In biodiversity rich regions such as Northeast India, TEK is deeply embedded in everyday cultural practices. Among these, the preparation of traditional food and beverages serves as a vital means for transmitting environmental knowledge across generations [1, 2]. Traditional fermented beverages play a vital role in indigenous diets, ritual life, and social cohesion, while also reflecting intricate relationships between cultural practices and local plant diversity. Their preparation and use embody accumulated ecological knowledge, making them important yet underexplored components of biocultural heritage. Among the *Bodo*, *Rabha*, and *Ahom* communities of Assam, traditional fermented beverages such as *jou*, *chuje*, and *laopani* represent more than just culinary heritage. These beverages are intimately tied to ritual practices, social cohesion, and ecological knowledge. Their preparation is a holistic process that embodies centuries of interaction with the local environment [3]. These indigenous beverage-making traditions are intricately linked to local biodiversity. The careful selection of rice varieties, herbs, leaves, and roots for fermentation reflects a sophisticated understanding of plant properties, habitat-specific availability, and seasonal cycles [4, 5]. Notably, women serve as the principal custodians of this knowledge, overseeing the entire process from plant collection to fermentation. In doing so, they uphold cultural identity while simultaneously safeguarding plant diversity [6, 7]. The use of wild and semi-cultivated plant species demonstrates how traditional beverage preparation is embedded in an ecological worldview that values sustainability and natural regeneration. These practices illustrate how indigenous knowledge systems contribute to in-situ biodiversity conservation while reinforcing community resilience [8, 9].

However, these intricate systems of knowledge and practice are increasingly under threat. Rapid urbanization, deforestation, the expansion of market-driven agriculture, and the erosion of indigenous customs are accelerating the loss of both cultural and biological diversity. The marginalization of traditional practices due to modernization and external cultural influences has led to a decline in the use of native plant species and the gradual disappearance of traditional fermentation techniques [10, 11] This disruption not only endangers cultural heritage but also weakens community-based strategies for managing local biodiversity. In this context, understanding the cultural ecology of traditional fermented beverages offers a valuable lens through which to explore the interconnections between indigenous knowledge, biodiversity conservation, and cultural continuity. Studying the practices of the *Bodo*, *Rabha*, and *Ahom* communities sheds light on how local ecological systems are maintained through traditional knowledge transmission and sustainable use of natural resources. Recent research has shown that traditional fermentation practices not only enrich local diets but also enhance microbiome diversity and support gut health, further linking these cultural practices to community well-being [12].

Despite increasing global interest in traditional fermented foods, indigenous beverage-making practices of Northeast India, particularly among the *Bodo*, *Rabha*, and *Ahom* communities, remain insufficiently studied. Earlier research has largely focused on cataloguing plant species or providing isolated ethnographic descriptions, with limited integration of botanical, biochemical perspectives, socio-cultural, ecological, and functional perspectives [13]. Existing studies on traditional fermented beverages largely

address botanical or sociocultural aspects in isolation, with limited integration of traditional ecological knowledge (TEK), quantitative ethnobotanical indices, and conservation outcomes. The roles of gendered knowledge transmission, ritual practices, and the resilience of intergenerational knowledge under socio-environmental change remain underexplored. To address these gaps, the present study adopts an integrative approach combining ethnobotany, ecology, and indigenous knowledge systems to: (i) document plant species used in fermented beverage preparation among the *Bodo*, *Rabha*, and *Ahom* communities; (ii) evaluate their cultural significance using quantitative indices; and (iii) examine the contribution of rituals and taboos to biodiversity conservation and ecological sustainability.

2 Methodology

2.1 Study area

This study adopts a qualitative, transdisciplinary research design that integrates ethnobotanical fieldwork, ecological assessments, and ethnographic methods to examine the traditional fermented beverage practices of the *Bodo*, *Rabha*, and *Ahom* communities in Assam. Assam is part of the Eastern Himalayan and Indo-Burma biodiversity hotspot and is characterized by tropical to subtropical ecosystems, including riverine floodplains, moist deciduous and evergreen forests, wetlands, and forest–agriculture mosaics. The region experiences a humid monsoonal climate with high annual rainfall (≈2000–3000 mm), warm temperatures, and pronounced seasonal variation, which together support rich floral diversity. Geographically, Assam is divided into two main river valleys, the Brahmaputra and the Barak valley, with the Brahmaputra Valley occupying the dominant portion of the state, whose fertile alluvial soils, extensive river networks, and forest edges create ideal conditions for diverse plant resources and traditional biodiversity-dependent practices.

For the present study, we have taken three dominant local alcoholic beverage preparing communities from three different strata of Brahmaputra valley during 2023 February to 2024. Communities were selected from two districts from each stratum. *Bodo* from lower and central Assam (Kokrajhar and Baksa districts), *Rabha* from lower and central Assam (Goalpara and Kamrup districts) and *Ahom* from upper Assam (Tinsukia and Dibrugarh districts) (Fig. 1). These areas were selected based on the prevalence of traditional beverage making practices, accessibility and willingness of community members to participate and share their knowledge in this study. Ethical consent was taken from every member participated in the discussion.

2.2 Interview-based data collection

A snowball sampling technique was employed to identify key informants, including elderly women, traditional brewers, herbalists, and community elders. A total of 30 informants (10 from each community) were interviewed with the help of questionnaire sheet, with a focus on women who are primary knowledge holders in beverage preparation. For Ethnographic data collection Semi-structured interviews, Participatory Rural Appraisal (PRA), Focus group discussions (FGDs) were conducted at different level. Semi-structured interviews were conducted in local language with elders, brewers, herbalists, and women, focusing on the cultural, ritual and ecological dimensions of local herbs used and utilization pattern in beverage preparation. The interviews followed a flexible guide

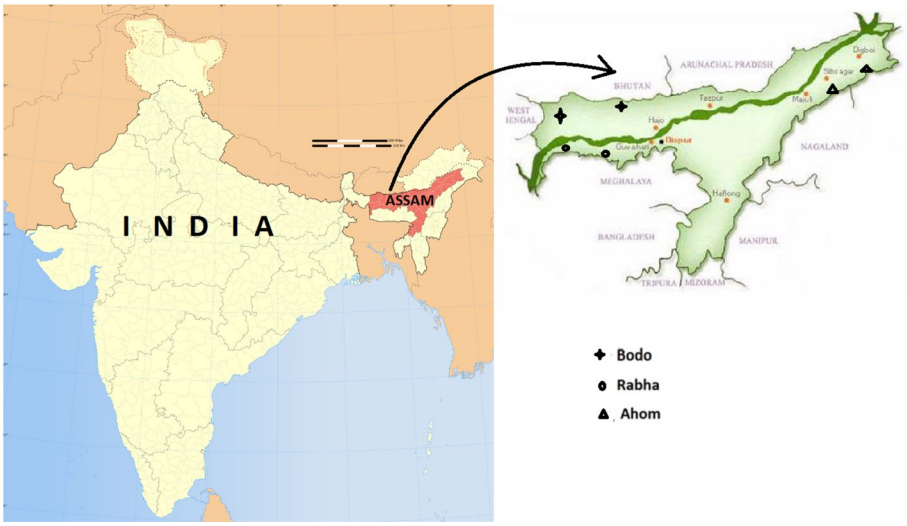


Fig. 1 Map of Assam showing study sites

that allowed participants to elaborate on their experiences and perspectives while ensuring consistency across respondents. Questions focused on the cultural, ritualistic, and ecological dimensions of local herbs used in traditional beverage preparation, as well as their collection, processing, and preservation practices. To ensure accuracy and cultural sensitivity, all interviews were conducted in familiar community settings, often in participants' homes or common gathering spaces. Responses were recorded through detailed field notes and, where consent was provided, with audio recordings for later transcription and cross-verification. The interviewer adopted a participatory and conversational approach to encourage open dialogue and build trust with respondents, particularly among women who are primary knowledge holders in beverage preparation. During several interviews, the research team actively participated in beverage preparation sessions to gain first-hand understanding of ingredient selection, brewing techniques, and associated symbolic meanings. This participatory engagement enriched the data by linking verbal narratives with observed practices, thereby enhancing the validity and contextual depth of the information collected. During data collection, where appropriate, we participated in the preparation of alcoholic beverage to understand the techniques, plant use, and symbolic meanings to understand it more accurately. FGDs were organized separately with women, elderly person, and local herb collectors/sellers to understand the plant use, beliefs, rituals, cultural and ecological values of the plants and continuity/change in the practices. Formal discussions on knowledge of local plants used in fermentation, seasonal patterns and taboos in harvesting, cultural values attached to biodiversity, practices of selective harvesting, propagation, and protection, perceptions of ecological change (plant scarcity, climate impact) were organized.

2.3 Plant specimen collection and identification

Interview session was followed by plant identification and collection from both wild and cultivated land. Plants used in fermentation were collected with the help of local guide. Documentation was done with its local name, part used, collection season, and method of preparation. Field visits were made to areas where plants are collected (e.g., forest edges, home gardens, fallow lands) to understand their ecological status (wild,

semi-cultivated, or cultivated). Conservation status of frequently used species was assessed based on IUCN categories, availability trends, and local perceptions of resource decline. Herbarium specimens were prepared and identified using regional floras and with the help of online identification - The plant list (https//www.plantlist.org) and deposited at Arunachal University of Studies.

2.4 Data analysis

Thematic analysis was used for qualitative data collected from semi-structured interviews, Participatory Rural Appraisal (PRA) and FGDs, focusing on recurring themes such as gender roles, ecological importance, traditional conservation strategies and cultural values. Use Value (UV) and Fidelity Level (FL) were calculated for each plant species to assess their cultural significance and frequency of use. Ecological data were analyzed to determine the sustainability of harvesting practices and habitat preferences of commonly used species.

1. Cultural Keystone Species Index

Cultural Keystone Species Index (CKSI) is developed to find out the most culturally important species [14]. A commonly used formula is:

$$CKSI = \sum (I_i \times W_i) / N$$

where: I_i: Importance or frequency score of species i for a specific cultural variable. W_i: Weight assigned to the cultural variable, indicating its relative importance. N: Total number of informants or total possible score (for normalization).

2. Use Value Index

The Use Value (UV) of medicinal plants serves as an indicator of their relative importance, calculated based on how frequently each plant is cited by informants [15]. It is determined using the formula.

$$\mathrm{UV} = \Sigma \mathrm{U_i}/\mathrm{N}$$

where, U_i represents the number of uses mentioned by each informant for a particular plant, and.

N is the total number of informants.

3. Fidelity Level

The Fidelity Level (FL) formula is applied to identify the culturally significant species by calculating the percentage of informants who identified a specific plant as their top choice for the same.

$$\mathrm{FL}\,(\%) = (\mathrm{I_p}/\mathrm{I_u}) \times 100$$

where, I_p is the number of informants who independently cited the use of a plant species for cultural use, and I_u is the total number of informants who reported using the plant for any type of use [16].

3 Results

The selected indigenous communities of Assam for this study, such as the *Bodo*, *Rabha*, and *Ahom* possess a wealth of ethnobotanical knowledge that is intricately linked to their cultural, spiritual, and ecological traditions. Among the most captivating expressions of this knowledge is the traditional preparation of alcoholic beverages. These drinks are not merely daily consumables but hold deep cultural significance, serving key roles in rituals, healing ceremonies, agricultural festivals, and social gatherings. A unique aspect of this cultural ecology is the sourcing of ingredients from small sacred groves, community-protected forest patches preserved through religious beliefs, taboos, and customary laws. These groves function as vital reservoirs of biodiversity and exemplify the harmonious relationship between spiritual reverence and sustainable resource use.

3.1 General preparation methods

Each community has developed its own distinct methods for brewing traditional rice-based alcoholic beverages. The *Bodo* people prepare a drink called *Jou*, made by steaming glutinous rice and mixing it with a traditional herbal starter culture known as *angkur.* The mixture is fermented in earthen pots for five to seven days, producing a mildly alcoholic drink that may also be distilled for a stronger variant. Similarly, the *Ahom* community brews a drink known as *Xajpani.* Cooked rice is cooled and combined with a fermented herbal cake (known as *Bakho*r among *Bodo* and *Rabha; Vekur pitha/Xajpitha* among *Ahom* community) crafted from local medicinal plants. This mixture is stored in bamboo or earthen containers and left to ferment naturally. The resulting beverage is typically consumed during cultural festivals and religious ceremonies. The *Rabh*a community prepares *choko*, a traditional drink made by fermenting boiled rice with herbal starter cakes sourced from forest plants. Fermentation is carried out in bamboo containers sealed with banana leaves, and the filtered liquid is consumed during both social and religious occasions.

3.2 Quantitative data

Despite differences in names and techniques, the core process across these communities remains consistent fermenting rice with herbal cultures in natural containers. In this study total 41 plants belonging to 29 families have been reported to be used by *Ahom*, *Bodo*, and *Rabha* communities in the preparation of traditional alcoholic beverages in Assam (Table 1). Method of preparation is almost similar, still there are some differences in cultural use and conservation strategies. This practice not only reflects their deep ecological understanding and spiritual beliefs but also reinforces their cultural identity and commitment to biodiversity conservation. These species represent a diversity of plant life forms, with herbs being the most prevalent (17 species), followed by shrubs (13), trees (9), climbers (4), and ferns (4). A majority of these plants are wild-sourced, indicating reliance on forest-based resources for their traditional practices.

Plant parts used in beverage preparation varied across species. Leaves were the most frequently used part, documented in 24 species, followed by aerial parts, roots, stems, bark, rhizomes, fruits, flowers, and bulbs (Fig. 2). In some cases, multiple parts of the same plant were used, such as the leaves and roots of *Desmodium caudatum* and *Pueraria montana*, suggesting the multifunctional utility of these species. The functional roles of plants in beverage preparation were diverse. Several plants were used primarily

for flavour enhancement, including *Cinnamomum tamala*, *Zingiber officinale*, and *Capsicum annuum*, while others contributed aroma and preservation qualities, such as *Syzygium aromaticum* and *Piper longum*. Plants like *Pueraria montana* and *Musa paradisiaca* were particularly important for aiding fermentation. *Scoparia dulcis* and *Drymaria cordata* were cited for taste enhancement, while some species contributed to the tightness of the dry fermentation cake called *Bakhar*, as seen with *Equisetum debile* and *Christella parasitica*. Unique uses also included the application of *Musa paradisiaca* leaves as a natural barrier in fermentation pots and the use of species such as *Drymaria cordata* and *Acanthus leucostachyus* for their cooling effects.

Beyond their functional roles in beverage production, most species had additional medicinal or ritualistic significance. For instance, *Scoparia dulcis* was associated with community rituals such as the *Gaonraja Puja*. Plants like *Piper betle* and *Mangifera indica* played essential roles in religious ceremonies, while *Zingiber officinale* and *Tinospora cordifolia* were well known for their therapeutic benefits in digestion, respiratory issues, and immunity. Many of these species are also consumed during the *Bohag Bihu* festival as part of *Aakho abidh sak* traditional mixture of a hundred and one edible leafy herbs highlighting their cultural value.

Cultural Knowledge Significance Index (CKSI) scores reflected the importance of certain plants within community traditions (Table 2). *Scoparia dulcis* had the highest CKSI value (0.68), closely followed by *Zingiber officinale* and *Tinospora cordifolia* (0.67 each). Other species like *Piper betle* (0.65), *Piper nigrum* (0.64), and *Capsicum annuum* (0.59) also ranked highly, signifying their widespread recognition and multifunctionality across different ethnic groups. These species were not only used for their functional role in beverage preparation but were also valued for their medicinal and ceremonial importance. The high CKSI species were predominantly wild and harvested during the peak monsoon and post-monsoon seasons (May to October), indicating both their seasonal abundance and traditional reliance.

Fidelity Level (FL) scores offered insight into the degree of informant consensus on plant usage (Table 3). *Musa paradisiaca* had the highest FL score (3.78), confirming its consistent and specific application as both a fermentation facilitator and physical barrier during processing. It was followed by *Zingiber officinale* (3.25), *Mangifera indica* (2.53), *Artocarpus heterophyllus* (2.4), and *Psidium guajava* (2.32). Other notable species included *Piper longum*, *Cinnamomum bejolghota*, *Vernonia cinerea*, *Scoparia dulcis*, and *Leucas aspera*. The overlap of high CKSI and FL values in species such as *Scoparia dulcis* and *Zingiber officinale* underscores their broad relevance across cultural, medicinal, and beverage-related domains.

In terms of sourcing, 85% of the species were collected from the wild (Fig. 3), while only a few, such as *Piper betle*, *Zingiber officinale*, and *Syzygium aromaticum* were cultivated. This reflects a deep dependency on natural ecosystems. Seasonal collection patterns revealed that most plants were gathered during the monsoon and post-monsoon months (May to October), coinciding with major cultural and agricultural activities in the region.

Although 24 of the 41 species were commonly used by all three ethnic groups, certain plants held particular importance within specific communities. For example, *Drymaria cordata* and *Croton joufra* were especially valued by the Ahom, while *Pouzolzia viminea* and *Plumbago zeylanica* were more ritualistically significant among the Rabha and Bodo.

Table 1 Plant species used in traditional alcoholic beverage prepared by *Rabha*, *Bodo* and *Ahom* along with their other cultural uses

Sl. No.	Local name/use community/voucher number	Scientific name/ lifeform	Family	Part used	Use in beverage preparation	Other uses (traditional medicinal, ritual etc.)	Source (wild/cultivated)	Season of collection	Abundance (rare/common)	CKSI score	FL score
1	Laaijabori/Ahom/ ST/EES/2024/015	*Drymaria diandra* (Sw.) Blume / Herb	Caryophyllaceae	Whole plant	As cooling agent and for medicinal property; for taste enhancement	Use in traditional medicine for headache, peptic ulcer, sleeping disorder. During *Bohag Bihu* this herb is consume with other hundred leafy herbs called *Aakho abidh sak*	Wild	Apr-Oct	Common	0.10	1.61
2	Pithadola/Ahom, Bodo ST/EES/2024/003	*Blumea balsamifera* (L.) DC./Shrub	Asteraceae	Leaf	Aromatic leaves with medicinal properties,	Dried or fresh leaves are burned to produce a fragrant smoke believed to ward off evil spirits and purify living spaces. This practice is common during: Housewarming rituals, Post-funeral cleansing, Festival preparations among *Ahom*; Among *Bodo* communities, the leaves are hung at doorways or worn to protect against bad omens or spiritual attacks	Wild	Oct-Nov	Common	0.13	1.12
3	Goropsoi/ Gorobchoi/Ahom ST/EES/2024/007	*Naravelia zeylanica* (L.) DC. /Shrub	Rananculaceae	Leaf, Stem	For flavour and aroma	Leaves are use in wounds and ulcers. Stem is used in tooth ache.	Wild	Oct-Jan	Common	0.18	1.26
4	Senibon/ senikuthi/Ahom, Bodo, Rabha ST/ EES/2023/012	*Scoparia dulcis* L./Herb	Scrophulariaceae	Aerial part	For sweetness and increased concentration.	The *Rabha* and *Bodo* communities celebrate "*Gaonraja Puja*," a ritual dedicated to their local deity, with the aim of ensuring village well-being and protecting against malevolent spirits	Wild	Jun-Sep	Common	0.68	1.89
5	Athukola/Ahom ST/EES/2024/010	*Chloranthus elatior* Link/Shrub	Chloranthaceae	Leaf	For concentration.	Traditional medicine for rheumatic pain	Wild	Apr-Jun	Rare	0.20	2
6	Bonguti/Ahom ST/EES/2024/011	*Ohwia caudata* (Thunb.) H. Ohashi/ Shrub	Fabaceae	Leaf and root	For tightness	Widely used in their magico-religious beliefs and rituals	Wild	Sep- Nov	Common	0.37	0.75

Table 1 (continued)

Sl. No.	Local name/use community/voucher number	Scientific name/ lifeform	Family	Part used	Use in beverage preparation	Other uses (traditional medicinal, ritual etc.)	Source (wild/cultivated)	Season of collection	Abundance (rare/common)	CKSI score	FL score
7	Khorkhori/ Raing/Ahom ST/EES/2023/017	*Croton joufra* Roxb./Tree	Euphorbiaceae	Bark and Leaf	For flavour, taste, deep concentration and clearness of liquor	Widely used in traditional medicine and as a spice in local cuisines. During *Bohag Bihu* this is consume with other hundred leafy herbs called *'Aakho abidh sak'* which boost immunity	Wild	Jan-Dec	Common	0.10	1.32
8	Jaluk/Bodo, Rabha ST/EES/2024/021	*Piper nigrum* L./Climber	Piperaceae	Seed	For flavour and taste enhancement	Seeds are used for bodyache, cold, cough and also given to the postnatal mother for first seven days after delivery	Wild	May- Jun	Common	0.64	1.5
9	Jolokia/Ahom ST/EES/2023/025	*Capsicum annuum* L./Shrub	Solanaceae	Fruit	For taste	Roots are used in asthma	Wild	May-Jul	Common	0.59	0.7
10	Bikh velengoni/Ahom , Rabha ST/EES/2024/015	*Pteridium aquilinum* (L.) Kuhn/Fern	Pteridaceae	Frond and root	For preservation	Leaves are used by *'vadiya'* (traditional healer) for pain relief	Wild	Jul-Sep	Common	0.13	0.48
11	Jom lakhuti/ Devi tokon/Ahom ST/EES/2023/019	*Hellenia speciosa (J.Koenig) S.R.Dutta/*Herb	Costaceae	Rhizome and Leaf	For deep concentration	Rhizomes are used for local deity worshiping	Wild	Oct- Dec	Common	0.20	1.4
12	Bar manimuni//Aho m, Bodo ST/EES/2024/018	*Centella asiatica* (L.) Urb. /Herb	Apiaceae	Whole plant	For taste enhancement	Good for gut health and prepare local cuisines. Immunity booster and consume with other hundred leafy herbs called *'Aakho abidh sak'* during Bohag bihu	Wild	May- June	Common	0.38	1.44
13	Anaras/Ahom Bodo, Rabha ST/EES/2024/022	*Ananas comosus* (L.) Merr. /Herb	Bromeliaceae	Tender Leaf	For reducing acidity	Leaves are used in traditional healing of jaundice	Cultivated	Dec-Jan	Common	0.50	1.44
14	Dhopattita/Aho m; Vetomali/Bodo ST/EES/2024/027	*Clerodendrum infortunatum* L./ Shrub	Lamiaceae	Leaf	For deep concentration	Used in traditional medicine for skin diseases	Wild	Apr- Aug	Common	0.23	1.38
15	Bor tubukilota/ Ahom, ST/EES/2024/020	*Cissampelos pareira* L./Shrub	Menispermaceae	Leaf	For flavour and preservation	Used for analgesic properties	Wild	Jul- Sep/ Aug-Oct	Common	0.07	0.32
16	Kapou dhekia/Ahom ST/EES/2024/026	*Lygodium flexuosum* (L.) Sw. /Fern	Schizaeaceae	Leaf	Stickiness	Rhizome is used for skin irritation curing and in rheumatism. Leaves are used for treating fractured bones	Wild	Aug- Feb	Common	0.17	1.04

Table 1 (continued)

Sl. No.	Local name/use community/voucher number	Scientific name/ lifeform	Family	Part used	Use in beverage preparation	Other uses (traditional medicinal, ritual etc.)	Source (wild/cultivated)	Season of collection	Abundance (rare/common)	CKSI score	FL score
17	Themra/Bodo, Rabha ST/EES/2024/028	*Acacia pennata* (L.) Willd./Tree	Fabaceae	Bark	For flavour	Stem, roots and leaves are burn and smoke believed to have protective power against negative energies	Wild	Aug- Sep	Common	0.38	0.5
18	Ada/Ahom, Bodo ST/EES/2023/035	*Zingiber officinale* Roscoe./Herb	Zingiberaceae	Bulb	For flavour, improve quality and for fermentation	Rhizome is good for digestion, and curing cough. A common spice.	Cultivat ed	Summer and winter	Common	0.67	3.25
19	Amrita/ Hogunilota/Aho m, Rabha ST/EES/2024/038	*Tinospora cordifolia* (Thunb.) Miers./ Shrub	Menispermacea e	Leaf	To improve gut health	Communities used for curing fever, gastric trouble and to improve immune system	Wild	May- June	Common	0.67	0.51
20	Chandramalika/ Ahom ST/EES/2024/030	*Chrysanthemu m indicum* L./Shrub	Asteraceae	Flower	For flavour enhancement	Used to decorate temples, local religious ceremonies	Wild	Aug-Oct	Common	0.16	0.54
21	Karpur gos/Ahom ST/EES/2024/031	*Camphora glandulifera* (Wall.) Nees./Tree	Lauraceae	Leaf and bark	For flavour	Essential oil extracted from this plant is a source of perfume and fragrance	Wild	Mar- May	Rare	0.29	1.54
22	Kuksim/Ahom ST/EES/2023/036	*Vernonia cinerea* L./Herb	Asteraceae	Leaf, root or stem	For flavour and act as a preservative	Used for curing cuts, skin problems. It is believe that it brings good luck and prosperity	Wild	Jun-Sep	Common	0.11	1.9
23	Doron/Ahom, Bodo ST/EES/2024/032	*Leucas aspera* (Wildd.) Link/Herb	Lamiaceae	Leaf and flower	For aroma	Flower used in local deity worshipping, leaves re edible herbs	Wild	Sep-Feb	Common	0.31	1.7
24	Paan/Ahom, Bodo, Rabha ST/EES/2024/009	*Piper betle* L./Climber	Piperaceae	Leaf	For taste	Used as a post meal mouth freshener. Offer in all rituals to the God/Goddess/local deity's puja along with betel nut.	Cultivated	Jun-Jul	Common	0.65	1.35
25	Aam/Ahom, Bodo, Rabha ST/EES/2024/013	*Mangifera indica* L./Tree	Anacardiaceae	Leaf	For flavour and taste	Fruits are edible, and seeds, barks are used in traditional medicine for asthma. Leaves are used as door hang during festivals and and used as spoons for pouring libations in every rituals	Wild	Jan-Mar	Common	0.38	2.53
26	Paruwa dhekiya/Ahom, Rabha, Bodo ST/EES/2024/016	*Christella parasitica* (L.) H. Lév./ Fern	Thelypteridacea e	Leaf	For tightness of dry cake called *Bakhar*	Traditionally use in rheumatic pain treatment by *Rabha, Bodo* community	Wild	Contain spores	Common	0.20	0.68

Table 1 (continued)

Sl. No.	Local name/use community/voucher number	Scientific name/ lifeform	Family	Part used	Use in beverage preparation	Other uses (traditional medicinal, ritual etc.)	Source (wild/cultivated)	Season of collection	Abundance (rare/common)	CKSI score	FL score
27	Laung/Ahom, ST/EES/2024/023	*Syzygium aromaticum* (L.) Merr. & L.M.Perry/ Tree	Myrtaceae	Dried, unopened flower bud	For flavour, aroma and as a preservative	It is a traditional spice used for preservation and used in traditional healing practice	Cultivated	Sep-Oct	Common	0.16	0.88
28	Athiya kol/Ahom, Rabha, Bodo ST/EES/2023/008	*Musa paradisiaca* L./ Shrub	Musaceae	Leaf	Leaves act as a natural barrier to prevent air from entering the fermentation pot	Fruits are edible; leaves are used for wrapping food, making plates, and serving dishes. Fibres are utilized in the production of textiles and twine.	Cultivated	Sep-Apr	Common	0.59	3.78
29	Khojo gosh/Rabha, Bodo ST/EES/2024/014	*Pouzolzia sanguinea* (Blume) Merrill/Herb	Urticaceae	Aerial part	For tightness of dry cake called *Bakhar*	Twigs are used in worshipping their local deity in '*Gaonraja puja*'	Wild	Nov- Mar	Rare	0.20	0.72
30	Boga agiya/ Agarsita/Rabha, Bodo ST/EES/2024/039	*Plumbago zeylanica* L./Herb	Plumbaginaceae	Root and stem	For concentration	Used in funeral ceremony	Wild	Sep- Nov	Common	0.03	0.45
31	Dingkhakhloi/ Phirphiria pat/Ahom, ST/EES/2024/040	*Thunbergia grandiflora* (Roxb. ex Rottl.) Roxb./Climbe r	Acanthaceae	Leaf	For flavour	Leaves are used in cuts, wounds	Wild	Jun-Jul	Common	0.11	0.3
32	Kothal/Ahom, Bodo, Rabha ST/EES/2024/044	*Artocarpus heterophyllus* Lam./Tree	Moraceae	Leaf	For aroma and cooling effect; helps in easy fermentation	Fruits are edible, leaves used in *Bakhor*, which is the main ingredient of local alcoholic beverage. This beverage is offered to their local deities, also offered during marriage ceremonies, rituals, family functions etc.	Wild	Dec- Mar	Common	0.48	2.4
33	Madhuriam/Aho m, Bodo, Rabha ST/EES/2024/024	*Psidium guajava* L./Small tree	Myrtaceae	Leaf	For good gut health	Used in homemade tea; healing practitioners used it for curing indigestion, loss of appetite, gastric ulcer	Wild	Feb- June	Common	0.33	2.32
34	Pipli/Ahom, Rabha ST/EES/2023/004	*Piper longum* L./ Climber	Piperaceae	Fruit	For warming effect and preservation	Common spice in many cuisines; matured fruits are widely used in cough and cold treatment by local healers	Cultivated	Oct-Jan	Common	0.33	2.25
35	Hargoza/Bodo ST/EES/2024/006	*Acanthus leucostachyus* Wall. Ex Nees/Herb	Acanthaceae	Aerial part	For cooling effect	Prepare local cuisines with its flower	Wild	Feb- April	Common	0.26	1
36	Bajramoni gos/Ahom, Bodo ST/EES/2024/033	*Zanthoxylum rhetsa* (Roxb.) DC./Tree	Rutaceae	Fruit	For flavour	Very common spice found in many cuisines	Wild	Mar- Nov	Common	0.17	1.36

Table 1 (continued)

Sl. No.	Local name/use community/voucher number	Scientific name/ lifeform	Family	Part used	Use in beverage preparation	Other uses (traditional medicinal, ritual etc.)	Source (wild/cultivated)	Season of collection	Abundance (rare/common)	CKSI score	FL score
37	Tejpat/ Bodo, Rabha ST/EES/2024/029	*Cinnamomum tamala* (Buch.-Ham.) T.Nees & C.H.Eberm. /Tree	Lauraceae	Leaf	For flavour and taste enhancement	Common spice	Wild	Mar-June	Common	0.33	1.26
38	Panimodhuri/Ah om ST/EES/2024/005	*Achyranthes bidentata* Blume./Herb	Amaranthaceae	Root	For slightly earthy taste	Hung above doorways or used in household rituals to ward off evil spirits or negative energies; healing rituals involving chants and offerings, especially for ailments believed to have supernatural origins.	Wild	July- Sept	Common	0.10	0.44
39	Pankoi/Ahom ST/EES/2024/034	*Cinnamomum bejolghota*(Buch.-Ham.) Sweet/Tree	Lauraceae	Leaf	For aroma	A spices use in local cuisines	Wild	April- July	Common	0.54	2.16
40	Gopsoi/Ahom ST/EES/2024/037	*Pueraria montana* var. *lobata* (Willd.) Sanjappa & Pradeep./ woody climber	Fabaceae	Leaf and root	The roots and leaves are used for speedy fermentation	Used during festivals, agricultural celebrations (like *Bihu*), and rituals such as ancestor worship, marriage ceremonies, and community feasts	Wild	Jun- Oct	Common	0.20	1.47
41	Saku dihinga/Ahom ST/EES/2024/041	*Equisetum debile* Roxb./ Herb	Equisetaceae	Whole plant	For tightness of dry cake called *Bakhar*	Traditional medicinal uses, for curing cuts, wound healing	Wild	May- July	Common	0.53	0.77

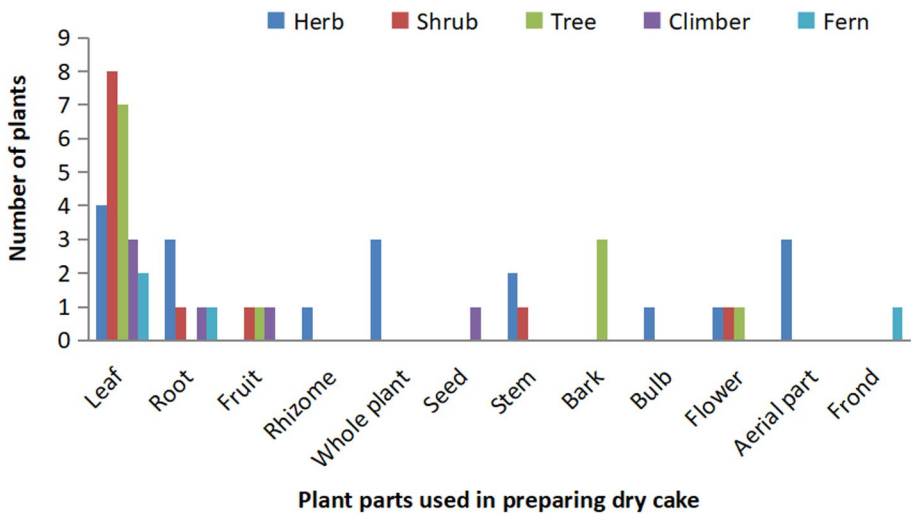


Fig. 2 Number of life forms and their parts used during preparation of dry cake

Table 2 Top ten CKSI species used by the communities

Species	CKSI
Scoparia dulcis	0.68
Zingiber officinale	0.67
Tinospora cordifolia	0.67
Piper betle	0.65
Piper nigrum	0.64
Capsicum annuum	0.59
Musa paradisiaca	0.59
Cinnamomum bejolghota	0.54
Equisetum debile	0.53
Ananas comosus	0.5

Table 3 Top ten FL species used by the communities

Species	FL
Musa paradisiaca	3.78
Zingiber officinale	3.25
Mangifera indica	2.53
Artocarpus heterophyllus	2.4
Psidium guajava	2.32
Piper longum	2.25
Cinnamomum bejolghota	2.16
Vernonia cinerea	1.9
Scoparia dulcis	1.89
Leucas aspera	1.7

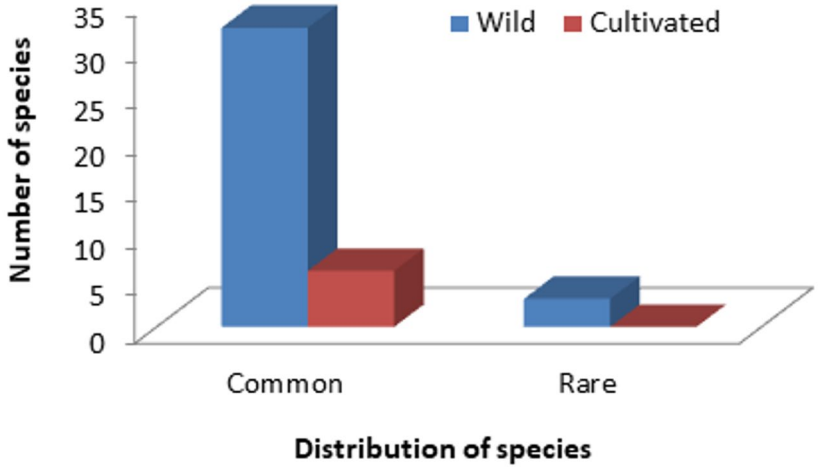


Fig. 3 Number of plant species distribution in different habitat

Nevertheless, widely shared species like *Piper betle*, *Scoparia dulcis*, and *Zingiber officinale* highlighted both the shared ethnobotanical knowledge and the ecological overlaps between these cultures.

3.3 Qualitative data

3.3.1 Taboos for collection

Participatory Rural Appraisal (PRA) and FGDs, were conducted to understand recurring themes such as gender roles, ecological importance, traditional conservation strategies and cultural values of this herb based alcoholic beverage preparation method. Mostly women involve in the herb collection, grinding, mixing rice flour, cake drying and preparation process. Sometime elderly male members were also collecting the herbs from the wild. Along with the harvesting practice, they also maintain the nature harmony by collecting minimum number of herbs, avoiding uprooting, which are rare in their local areas. Hence, it can be said that all the communities follow certain taboos which in turn help to conserve the resources available in their nearby forest. The best example is the sacred groves or *Thans* found in many places of the study sites. Among *Bodo* and *Rabha* community those places were only visited during rituals, ceremonies. Collection of herbs mostly used in *Bakhar* or dry cake was done from those sacred places, more specifically for worshipping their local deities, clan gods. These ecological sanctuaries harbour a variety of medicinal, culturally significant plants, including herbs used in preparation of rice-based fermented beverages. These groves are typically community-managed and preserved through customary regulations, which prohibit activities like tree felling, grazing, and overharvesting. The belief systems of local *Rabha* and *Bodo* people not only help to preserve locally rare and ecologically sensitive plant species but also promote ethical harvesting practices. They have very strict instruction from village head (*Gaonbura*), for seasonal harvesting, uprooting is prohibited, only required item can collect, selective cutting and rotation is allowed. Similarly, herbs in the fermentation starter (*vekur*) used by the *Ahom* community were obtained from *'Thans'* (sacred shrines) or *'Deohal'* (ancestral altars). The brewing of *Xajpani* holds profound spiritual significance. The process typically begins with ritualistic offerings of betel leaf and areca nut, symbolizing respect

and seeking favor from nature spirits. It is commonly believed that when the ingredients are gathered in a respectful and ethical manner, forest deities bless the final brew.

3.3.2 Taboos follow during preparation

In the *Bodo* community, the preparation of *jou* is considered a sacred activity, surrounded by several taboos. Only individuals who are ritually clean are permitted to take part in the brewing process. Women undergoing menstruation are strictly prohibited from participating, and those involved in the brewing must bathe and wear fresh clothes before handling any ingredients. The brewing space must be kept clean and undisturbed, as it is believed that any form of conflict, loud talking, or negative energy could spoil the fermentation process. Additionally, before the beverage is consumed, it is customary to offer the first portion to deities and ancestors, invoking their blessings and maintaining spiritual harmony. Similarly, the *Rabha* community observes several spiritual and cultural restrictions during the making of *chubitchi*, their traditional rice beer. The process is often conducted in a secluded, designated space, and the presence of outsiders or non-community members is discouraged. Ritual purity is emphasized, with participants often abstaining from sexual activities in the days leading up to and during the brewing period. As with the *Bodo*s, menstruating women are not allowed near the brewing area. These taboos reflect a deep respect for the beverage as a sacred medium connecting the human and spiritual worlds. The *Ahom* community, known for preparing *haaj* or *laopani*, also follows similar customs. Historically, only certain clans or ritually pure women were allowed to prepare the drink, especially when it was intended for religious or ancestral offerings. Cleanliness of the body, mind, and environment is considered essential. Utensils used in brewing must be washed thoroughly, and the process is often carried out in silence or with a solemn attitude. The first portion of the drink is typically offered to the ancestors, reinforcing its role in ritual communication and ancestral veneration (Fig. 4).

Across these communities, the taboos associated with traditional alcoholic beverage preparation serve several functions, they ensure hygienic practices, reinforce social and gender norms, and maintain a sense of spiritual reverence. These customs are not merely

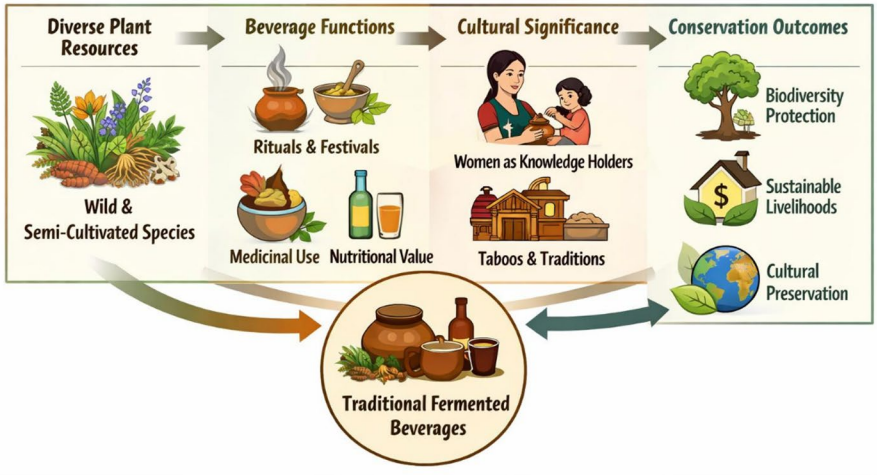


Fig. 4 Conceptual framework linking plant resource diversity, traditional fermented beverage functions, cultural practices, and conservation outcomes among the indigenous communities

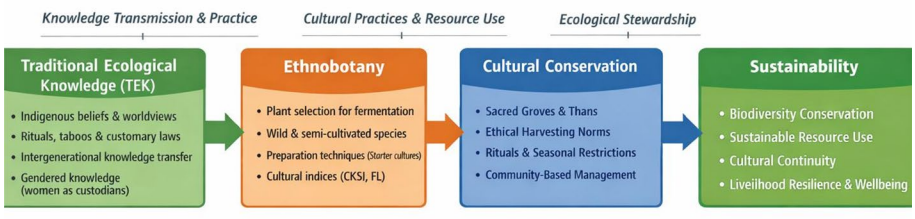


Fig. 5 Conceptual framework illustrating the linkage between Traditional Ecological Knowledge (TEK), ethnobotanical practices, cultural conservation, and sustainability outcomes in indigenous fermented beverage systems

superstitions but are integral to the cultural ecology of indigenous life. They help safeguard the quality of the drink, preserve community values, and sustain the sacred relationship between humans, nature, and the spiritual world. As such, understanding these taboos provides valuable insight into the intertwined nature of Indigenous knowledge systems, environmental ethics, and cultural continuity in Assam (Fig. 5).

4 Discussion

4.1 Quantitative data

The present study highlights the integral role of 41 plant species used by the *Ahom*, *Bodo*, and *Rabha* communities in Assam's traditional alcoholic beverage production. This ethnobotanical documentation aligns with previous surveys such as Duarah et al. [17] who reported 51 species across six ethnic groups including *Ahom*, *Bodo*, and *Rabha* in rice beer starter culture preparations, emphasizing multifunctional uses ranging from fermentation to therapeutic purposes. Also, study suggests a shared cultural and ecological knowledge base, reinforcing the importance of such ethnobotanical surveys for conserving region-specific biodiversity used in fermentative traditions [17]. One of the most significant results was the high CKSI for *Scoparia dulcis*, *Zingiber officinale*, and *Tinospora cordifolia*. Previous studies have also reported that *S. dulcis* use in rice beer by multiple tribes in Assam for beverage preparation and medicinal use (particularly for diabetes and stomach issues) [18, 19]. Notably, the high FL scores for *Musa paradisiaca* and *Z. officinale* reflect their specialized and consensus-based ethical use that appears crucial to fermentation processes. High CKSI values (e.g., 0.68 for *Scoparia dulcis*) are now explicitly interpreted as reflecting multifunctional importance, frequent citation across communities, ritual significance, medicinal value, and a central role in fermentation practices. Ecologically, such high CKSI species indicate sustained dependence on particular wild plants, underscoring their relevance for conservation prioritization. Similarly, high Fidelity Level values (e.g., 3.78 for *Musa paradisiaca*) are now contextualized as indicators of strong informant consensus regarding specific functional roles, such as its consistent use as a fermentation facilitator and physical barrier during brewing. Culturally, this reflects standardized knowledge transmission and shared norms across ethnic groups, while ecologically it highlights species that are deliberately conserved through cultivation or careful harvesting. Findings regarding *S. dulcis* have promising biomedical implications [20]. Recent pharmacological reviews indicate that the plant contains over 115 bioactive metabolites with treatments aimed at metabolic syndrome, including glycemic control, lipid modulation, and anti-inflammatory effects [21, 22]. A clinical crossover trial demonstrated that *S. dulcis* porridge significantly reduced HbA1c in Type 2 diabetics without adverse clinical markers [23]. This convergence of ethnobotanical

use and clinical pharmacology highlights that its usage in traditional beverages may convey tangible health benefits likely a factor in its elevated cultural significance. Concurrently, the tradition of using phytochemically active species like *Piper betle*, *Syzygium aromaticum*, and *Capsicum annuum* for flavor, preservation, and microbial modulation aligns with ethnobotanical and food-science studies from the Northeast. *Monpa* tribes in Arunachal Pradesh similarly use *Piper betle* and other herbs in starter culture phamzas' to foster beneficial fermentation microbiota [23]. This suggests a shared empirical understanding across regional traditions that such plants promote healthy fermentation possibly guiding microbial dynamics and inhibiting spoilage. Results further document how 85% of species were wild-sourced and predominantly harvested during the monsoon/post-monsoon (May-October). This timing coincides with major *Bihu* and agricultural festivities, a season when rice-based beverages are culturally significant, much like *Apo* among the *Mising* community (also prepared post-harvest for festivals). The convergence of linguistic, ritual, and seasonal cues underscores how agro- ecological cycles shape ethnobotanical practices, fostering transmission of ancestral knowledge across generations. Community-specific plant use like *Drymaria cordata* and *Croton joufra* by *Ahom*, or *Pouzolzia viminea* by *Bodo/Rabha* reflects localized adaptations within a shared regional framework. However, the presence of a core set of high-CKSI species used across all groups, especially in fermentation starter culture preparation, may indicate historic pathways of cultural diffusion and ecological convergence. This aligns with findings by Das et al. [24], highlighting how rice beer preparation methods and plant ingredients show marked consistency across Northeast Indian communities. The study also emphasizes the importance of documenting traditional practices before they are lost, and further, underscores a strong case for bioactivity-guided biochemical investigations to evaluate the health impacts of beverage ingredients like *S. dulcis*, *Z. officinale*, and *Tinospora cordifolia*.

4.2 Qualitative data

The observation of taboos related to the collection and preparation of traditional fermented beverages among the *Bodo*, *Rabha*, and *Ahom* communities of Assam highlights the integral role of indigenous knowledge systems in biocultural conservation. These culturally embedded restrictions not only reinforce social cohesion and spiritual observance but also serve as effective ecological safeguards. The practice of restricting access to sacred groves, such as *Thans* or *Deohals*, aligns closely with the concept of socio-ecological sanctuaries' [25], where religious and cultural values intersect with biodiversity conservation. These groves, managed under customary law, play a critical role in conserving medicinal and rare plant species, including those used for making fermentation starters. By prohibiting unsustainable harvesting practices such as uprooting or over-collection these communities exercise a form of community-based resource governance that aligns with modern conservation principles [26, 27]. Ritualistic limitations, such as seasonal collection, gender-based restrictions, and adherence to purification rites, further reflect a deep ecological sensibility. For instance, excluding menstruating women or enforcing abstinence during fermentation are not merely symbolic, but often rooted in maintaining microbial stability, hygiene, and sanctity of the brewing process. Similar practices have been reported among other indigenous groups globally, where

fermentation is seen as both a biological and spiritual transformation requiring ritual purity [28, 29].

The spiritual framing of fermented beverage preparation manifested in offerings to deities and ancestors, reveals a sacred epistemology where humans are part of a larger ecological-spiritual continuum. In the *Bodo* and *Rabha* contexts, the act of offering the first portion of the drink to spirits or ancestors reflects animistic traditions that help sustain both ecological integrity and ancestral memory. Among the *Ahom*s, this act of reverence is deeply tied to clan identity and ancestral communication, suggesting that brewing is not merely a domestic task, but a ritual act of cultural continuity [30]. Moreover, such taboos support social regulation and intergenerational knowledge transfer. They delineate who may participate, when, and under what conditions, thus embedding ecological responsibility within social norms. This resonates with the view that TEK systems often function through informal institutions like taboos, which regulate human interaction with the environment while embedding values of respect and restraint [31, 32].

Understanding these cultural prohibitions is essential not only for ethnobotanical documentation but also for policy frameworks that aim to integrate Indigenous perspectives in biodiversity management. In light of global calls for inclusive conservation, such as those outlined in the Convention on Biological Diversity, 2020 [33], these community-rooted practices offer replicable models for sustainable and ethical use of forest resources. Therefore, these taboos, far from being obsolete superstitions, represent sophisticated systems of bio-cultural resilience. They reinforce hygienic protocols, uphold social order, and enshrine spiritual stewardship, ensuring that the preparation of traditional alcoholic beverages remains a holistic process involving ecological mindfulness and cultural reverence. Also, we can observe the integration between quantitative indices (CKSI and FD) and qualitative ethnographic findings. Specifically, species with high CKSI values (e.g., *Scoparia dulcis*, *Zingiber officinale*, *Tinospora cordifolia*) are not only frequently cited and multifunctional, but are also embedded within ritual taboos, sacred grove protection, and ceremonial practices documented through PRA and FGDs. The elevated CKSI of these species reflects their dual role as functional ingredients in fermentation and culturally regulated species, where taboos on harvesting time, collection methods, and ritual purity limit overexploitation. For example, *Scoparia dulcis* shows high CKSI because it is simultaneously central to beverage preparation, ritual observances such as *Gaonraja Puja*, and sacred-grove–based conservation practices. Thus, the quantitative prominence of these species is directly shaped by qualitative cultural norms that reinforce sustainable use.

4.3 Limitations and future opportunities

Despite the valuable insights generated through this interdisciplinary study, several limitations were there. The research focused on three indigenous communities the *Bodo*, *Rabha*, and *Ahom* from selected districts in Assam, which may not comprehensively represent the broader diversity of traditional beverage-making practices across Northeast India. The relatively small sample size of 30 informants, while rich in depth, restricts the generalizability of certain cultural or ecological patterns. Also, because of seasonal constraints, some plants used in other times of the year may have been missed, potentially limiting the full ethnobotanical record. Although, indices such as the CKSI and FL

were calculated to gauge cultural significance, but did not incorporate biochemical or microbial analysis to validate the functional or medicinal claims associated with many of the documented species. Additionally, there was no focused assessment of the economic or market potential of these beverages, which limits insights into their commercial viability. On the other hand, if we see the future research opportunity, several exciting pathways are available. Detailed biochemical profiling and microbial characterization of these fermented beverages could reveal their nutritional and pharmacological properties, strengthening their value in both traditional medicine and functional food markets. Many of the plants used, such as *Scoparia dulcis*, *Zingiber officinale*, and *Tinospora cordifolia*, are already recognized globally for their medicinal properties, creating an opportunity to position these beverages within the growing nutraceutical and functional food sectors. There is strong potential to develop artisanal or microbrewery-scale production units that maintain traditional techniques while meeting hygiene and food safety standards. These enterprises could be community-led or involve public- private partnerships to ensure local benefit sharing. Additionally, pursuing Geographical Indication (GI) tagging for these heritage beverages would not only preserve indigenous intellectual property but also enhance their market value. Expanding the ethnographic scope to include other indigenous groups like the *Mising*, *Dimasa*, and *Karbi* could provide a more holistic understanding of the region's fermentation traditions. In the face of climate change, it is also essential to investigate how shifting ecological conditions affect the availability of key plant species and fermentation success. Furthermore, the integration of Indigenous fermentation knowledge into biodiversity and agro-ecological policy frameworks could reinforce both conservation and cultural continuity in the region.

5 Conclusion

The traditional fermented beverage practices of the *Bodo*, *Rabha*, and *Ahom* communities demonstrate the use of a rich diversity of plant species, largely sourced from wild and semi-cultivated habitats, to prepare beverages that are integral to rituals, seasonal festivals, and traditional healthcare systems. Culturally embedded taboos associated with plant collection and brewing reinforce conservation ethics and sustainable resource use. Within this framework, women emerge as the primary custodians of knowledge, playing a crucial role in the transmission of fermentation techniques, plant selection, and ritual protocols across generations through experiential and matrilineal learning. Despite their cultural and ecological significance, these traditions are increasingly threatened by modernization, habitat degradation, and the erosion of indigenous practices. Nevertheless, the resilience of these systems underscores their potential contribution to conservation and sustainable development frameworks. With appropriate scientific validation, supportive policies, and ethical commercialization strategies, traditional fermented beverages hold promise not only for safeguarding cultural heritage but also for enhancing local livelihoods and contributing to emerging global wellness markets.

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1007/s44187-026-01101-w.

Supplementary Material 1.

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Author contributions
ST arranges, analyzed the data and wrote the text; BS and HT collected samples, prepared herbarium, conducted field survey and DSJ contributed towards review, editing and supervising the draft.

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Data availability
The key findings of this study are presented in the article, and any further questions may be addressed to the corresponding author.

Declarations

Ethics approval and consent to participate
The participants were informed about the purpose of this study and consent was taken from each participant in the study. The participants were informed about the purpose of this study and consent was taken from each participant in the study. The Institutional Human Ethics Committee, Arunachal University of Studies University, Namsai, India, has waived the requirement for formal ethical approval for this study, as it involved non-invasive procedures. All procedures followed the AUS University Ethical Guidelines for Social and Behavioral Research involving humans.

Consent for publication
Consent was taken from all the participants for publication.

Competing interests
The authors declare no competing interests.

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