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HADIA KB as an Evidence Preserving Digital Knowledge Infrastructure for Traditional Rice Beer in Jharkhand India

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Abstract

Traditional knowledge about Handia, Hadia and Haria is valuable but digitally fragmented across ethnobotany, fermentation science, microbiology, nutrition, cultural studies, policy and law. We present HADIA-KB, an evidence-linked knowledge infrastructure that preserves source provenance, reported terminology and geographic scope instead of collapsing heterogeneous regional traditions into a single recipe or truth claim. Version 1.0 contains 29 indexed sources, 34 verified claim records, 16 plant or lichen records, 12 microorganisms, 18 quantitative measurements and 192 source-carrying graph relations. A reproducible pipeline converts public documentation into normalized entities, claim-level evidence passports, contextual-difference records and machine-readable graph exports. Empirical analysis shows a marked documentation imbalance: only 12 of 34 claims concern Jharkhand, while microbiology, chemistry, nutrition and metabolomics have no Jharkhand-specific claim in the frozen corpus. The evidence graph contains 125 nodes, 192 directed edges and two weakly connected components; claim attribution is distributed across an effective 22.27 sources rather than dominated by a single document. HADIA-KB therefore contributes not another description of rice beer, but an auditable map of what is documented, where evidence applies, where sources differ, and what remains unstudied. The accompanying software supports exploration, filtered export, graph analysis and reproducible extension by researchers, communities, and policymakers worldwide.

Keywords: Handia; Hadiya; rice beer; traditional knowledge; evidence knowledge graph; digital heritage

1 Introduction

Traditional fermented beverages are not merely biochemical products. They are socio-technical systems in which grains, starter cultures, locally available plants, microorganisms, sensory practice, ritual use, ecological conditions, and intergenerational knowledge are jointly entangled. Across India, research has documented extensive diversity in fermented foods and alcoholic beverages, from early descriptive work to modern sequence-based microbiology and metabolomics

(Achaya, 2003; Prakash, 1961; J. P. Tamang, 2010, 2020, 2022; J. P. Tamang et al., 1988, 1996, 2012, 2016, 2020, 2021). This broader literature shows that fermentation knowledge is locally organized and that seemingly similar beverages may encode distinct starter ecologies, plant mixtures, microbial consortia, and cultural meanings (Anupma & Tamang, 2020; Anupma et al., 2018; Jeyaram et al., 2008, 2011; Pradhan & Tamang, 2019, 2021; Sha et al., 2016, 2017, 2018, 2019; J. P. Tamang et al., 2007; Tanti et al., 2010; Tsuyoshi et al., 2005).

Handia, Hadia, Hadiya, Handiya, and related Haria forms are prominent examples in eastern India. Jharkhand-specific studies document Handia and its starter Ranu in ethnobotanical and cultural contexts (District Administration Khunti, 2026; Ghosh-Jerath et al., 2015; Government of Jharkhand, 2026; Kuiry, 2025; Kujur & Kandir, 2015, 2016; Kumar & Kumari, 2011), while policy and law simultaneously frame local production, livelihood transition, and alcoholic-beverage regulation (Food Safety and Standards Authority of India, 2025; Government of Jharkhand, 2020, 2021; India Code, 1915). Comparative work from West Bengal and Odisha adds detailed process, microbial, biochemical, nutritional, and metabolomic evidence (Alam et al., 2025; Bisai et al., 2023; S. Das et al., 2022; K. Ghosh, Ray, Adak, Dey, et al., 2015; K. Ghosh, Ray, Adak, Halder, et al., 2015; K. Ghosh et al., 2014, 2021; S. Ghosh et al., 2022; Nayak et al., 2026; Panda & Bastia, 2013; Panda et al., 2014; Ray et al., 2017; Sahoo, 2017). Reviews and public-facing documentation further demonstrate how rapidly claims can circulate beyond the contexts in which they were originally observed (Bharathidasan University, 2010; Hembrom et al., 2022; Nandi, 2024; National Library of Medicine, 2015; The Locavore and Dipatoli community, 2026).

The scientific problem is therefore not a shortage of isolated statements. It is a shortage of infrastructure for keeping statements attached to provenance, geography, terminology, method, and uncertainty. A numerical result from a West Bengal Haria study cannot automatically become a property of Jharkhand Handia; a starter name used in one region should not silently replace another; an in-vitro antioxidant assay is not clinical evidence; and absence from an indexed corpus is not evidence that a community lacks knowledge. These distinctions become especially important when digital resources are designed for reuse, discovery, machine learning, policy, or heritage communication.

Open-data practice offers tools for addressing part of this problem. FAIR emphasizes findability, accessibility, interoperability, and reusability (Wilkinson et al., 2016), while CARE emphasizes collective benefit, authority to control, responsibility, and ethics for Indigenous data governance (Carroll et al., 2020; Global Indigenous Data Alliance, 2019; Russo Carroll et al., 2021). Provenance standards, semantic-web vocabularies, research-object packaging, persistent citation metadata, and software citation principles provide complementary technical foundations (Citation File Format Community, 2021; DataCite Metadata Working Group, 2024; Dublin Core Metadata Initiative, 2020; Ehrlinger & Wöß, 2016; Guha et al., 2016; Hogan et al., 2021; Katz et al., 2021; Moreau, Missier, et al., 2013; RO-Crate Community, 2024; Smith et al., 2016; Soiland-Reyes et al., 2022; World Wide Web Consortium, 2009, 2013, 2014, 2020). Yet open technical infrastructure alone is insufficient for traditional knowledge: safeguards are also needed

against flattening community specificity, detaching knowledge from its custodial context, or treating public accessibility as unrestricted ownership (Convention on Biological Diversity, 1992, 2010; Local Contexts, 2026; UNESCO, 2003, 2024; World Intellectual Property Organization, 2026).

This paper presents HADIA-KB, a reproducible, claim-level, evidence-preserving digital knowledge infrastructure for publicly documented Handia/Hadia/Haria knowledge, with Jharkhand as the primary focus and comparative regional evidence explicitly retained. The work makes five contributions. First, it defines a source-linked data model in which evidence-bearing claims remain attached to provenance. Second, it enforces geographic and terminological fidelity rather than collapsing regionally heterogeneous evidence. Third, it distinguishes contradictions from contextual differences. Fourth, it converts the frozen corpus into multiple reusable representations, including CSV, XLSX, JSON, JSON-LD, RDF/Turtle, GraphML, PostgreSQL schema, and API-accessible data. Fifth, it quantifies the documented evidence landscape and exposes research gaps without equating missing documentation with missing knowledge.

2 Related Work and Scientific Context

2.1 Rice-based fermentation and starter ecologies

Modern rice-beer research spans culture-dependent microbiology, metagenomics, metabolomics, community surveys, functional assays, and starter-culture ethnobotany. Assam provides some of the richest comparative evidence: Xaj-pitha metagenomics and safety assessment, multi-beverage microbiome/metabolite analysis, emao community structure, community-specific ethnobotany, and recent systematic synthesis (Barman et al., 2026; Bora et al., 2016; A. J. Das & Deka, 2013; S. Das et al., 2019; Duarah et al., 2023; Gogoi, 2021; Keot et al., 2020; Loying et al., 2024; D. Narzary et al., 2021; Nath et al., 2019; Saikia et al., 2024; Yumnam et al., 2026). Work from Tripura, Himachal Pradesh, Sikkim, Manipur, and the wider Himalayan region similarly demonstrates that starter microorganisms and plant recipes are diverse rather than universal (Handa & Sharma, 2016; Y. Narzary et al., 2016; Nath et al., 2016; J. P. Tamang & Thapa, 2006; Thakur et al., 2015; Thapa & Tamang, 2004, 2006).

The wider Indian fermentation literature is relevant because it establishes methodological expectations for studying microbial succession, functionality, probiotic potential, food safety, and fermentation ecology (Basappa et al., 1997; Batra & Millner, 1974; Blandino et al., 2003; Daba et al., 2021; A. Das et al., 2012; G. Das et al., 2016; Goel et al., 2020; Keisam et al., 2016, 2019; Leeuwendaal et al., 2022; Linares et al., 2017; Marco et al., 2017; Mukherjee et al., 1965; Payyappallimana & Venkatasubramanian, 2016; Sanjukta & Rai, 2016; Satish Kumar et al., 2013; Soni & Sandhu, 1990; Swain et al., 2014). These studies also show why analytical comparability depends on sample state, fermentation stage, identification method, and unit conventions.

2.2 From literature review to evidence infrastructure

Traditional reviews synthesize narrative knowledge, but they do not necessarily preserve a machine-actionable audit trail from each normalized statement back to source wording and geographic context. Systematic-review reporting standards such as PRISMA improve transparent selection and reporting (Page et al., 2021), while reproducible computational research requires explicit workflows, stable environments, versioned outputs, and traceable software (Nosek et al., 2015; Peng, 2011; Sandve et al., 2013). HADIA-KB uses these principles without claiming that v1.0.0 is an exhaustive systematic review. Instead, the frozen release is treated as a versioned evidence corpus whose coverage can be measured and extended transparently.

3 Materials and Methods

3.1 Frozen evidence corpus

The analysis used the attached HADIA-KB v1.0.0 public evidence release as the sole source for all corpus counts and quantitative results. The release contains source, claim, plant, microorganism, measurement, terminology, location, community, policy/legal, relation, contextual-difference, and gap tables. The wider literature cited in this manuscript provides scientific context but does not alter the frozen dataset counts.

Figure 1 summarizes the end-to-end construction logic from source discovery through evidence-preserving normalization, validation, and release.

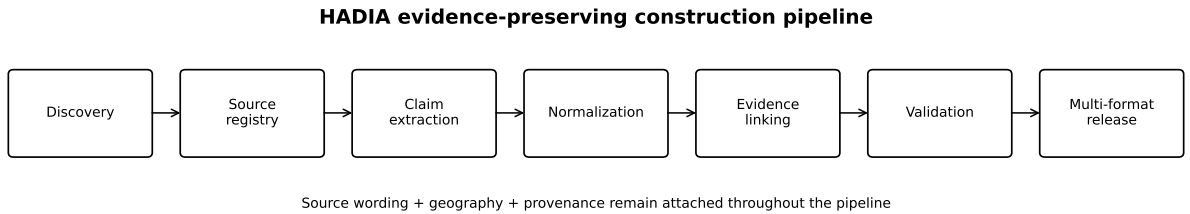


Figure 1: Evidence-preserving HADIA construction pipeline. Source terminology, geography, and provenance are retained throughout normalization and release.

The principal data components and record counts of the frozen release are summarized in Table 1.

Table 1: Core HADIA-KB v1.0.0 data components.

Component	Records	Role
Sources	29	Bibliographic/government/legal/public records
Claims	34	Claim-level paraphrases linked to sources
Plants/lichens	16	Reported starter-culture ingredients
Microorganisms	12	Reported taxa with identification method
Measurements	18	Quantitative values with unit and sample context
Relations	192	Source-carrying graph edges
Names/aliases	10	Reported beverage/starter terminology
Locations	7	Display geographies with precision metadata

3.2 Evidence passport and provenance constraints

Each claim is modeled as an evidence-bearing object rather than a free-floating fact. At minimum, the record stores a stable claim identifier, source identifier, claim category, paraphrased claim text, geographic scope, reported beverage name, evidence directness, verification state, and an interpretation caution where necessary. Source metadata are maintained separately so that many claims can point to one source without duplicating bibliographic information.

Algorithm 1 formalizes the evidence-linked ingestion procedure used to preserve provenance at claim level.

Algorithm 1: Evidence-linked claim ingestion

Input: Eligible public source s ; source metadata m_s

Output: Validated claim records and evidence relations

- 1 Register s with immutable source identifier S_i ;
 - 2 Extract candidate evidence-bearing statements $c_1, \dots, c_k$;
 - 3 **foreach** c_j **do**
 - 4 record wording context and source locator;
 - 5 assign name, geography, category, and directness;
 - 6 paraphrase without strengthening the claim;
 - 7 attach caution against over-generalization;
 - 8 validate traceability to S_i ;
 - 9 emit C_j with support relation to S_i ;
 - 10 Freeze accepted records into a versioned release;
-

3.3 Context-safe normalization

Normalization is deliberately conservative. “Handia” is used as a canonical database label, while Hadia, Hadiya, Handiya, Haria and starter names such as Ranu, Bakhar, Bhakar, Dabai, and Mod pitha are preserved as source-reported terms. Geographic scope is never inferred more

precisely than the source supports. Likewise, a culture-based microbial identification, a 16S sequence, PCR-DGGE profile, and metabolomic signal are not treated as equivalent measurement types.

Algorithm 2 formalizes the context-safe normalization rule used to prevent inappropriate collapse of heterogeneous records.

Algorithm 2: Context-safe normalization and difference preservation

Input: Record r with reported term n , scope g , method m , value v

Output: Normalized entity link plus preserved source context

- 1 Map n to a canonical entity only if the mapping is terminological, not evidentiary;
 - 2 retain n as `name_as_reported`;
 - 3 retain g as the applicability boundary;
 - 4 retain m , sample state, unit, and fermentation stage for measurements;
 - 5 **if** *two records differ* **then**
 - 6 test whether geography, sample state, method, or stage explains the difference;
 - 7 **if** *context explains difference* **then**
 - 8 store `contextual_difference`
 - 9 **else**
 - 10 store unresolved contradiction candidate
 - 11 Never propagate a regional value to another geography without explicit evidence;
-

3.4 Graph construction and coverage metrics

The relation table was interpreted as a directed graph $G = (V, E)$ where subject and object identifiers form nodes and relation predicates form typed directed edges. We computed node and edge counts, directed density, weakly connected components, and claim-source concentration. If p_i is the fraction of claims attributed to source i , the Herfindahl-Hirschman concentration index is

$$\text{HHI} = \sum_i p_i^2, \quad (1)$$

and source-attribution Shannon entropy is

$$H = - \sum_i p_i \log_2 p_i, \quad (2)$$

with effective source count $N_{\text{eff}} = 2^H$. These metrics describe corpus structure, not source quality.

Geographic documentation was coded into Jharkhand, West Bengal, Odisha, and India-wide/other classes from the explicit scope fields. A category was flagged as a documented-evidence gap for Jharkhand when the frozen corpus contained zero or only sparse Jharkhand-specific claims. This flag is explicitly not an estimate of real-world knowledge absence.

Algorithm 3 formalizes documentation-gap reporting while preventing missing records from being interpreted as evidence of real-world absence.

Algorithm 3: Context-aware documentation-gap detection

Input: Claims C ; target geography g^* ; topics T

Output: Gap indicators D

```
1 foreach  $t \in T$  do
2    $n_t \leftarrow$  count of supported claims for  $(t, g^*)$ ;
3   if  $n_t = 0$  then
4     label “not documented”
5   else
6     if  $n_t$  is sparse then
7       label “sparse”
8     else
9       label “represented”
10  attach the standard non-absence caution;
11 Return versioned indicators  $D$ ;
```

3.5 Reproducibility and open release

All reported analyses were generated from the frozen CSV tables using Python. Figures were generated programmatically, and the repository provides machine-readable exports, a PostgreSQL schema, API code, a Streamlit exploration interface, automated tests, and citation metadata. The archived software/data release is identified by DOI [10.5281/zenodo.22132285](https://doi.org/10.5281/zenodo.22132285). The methodological stance follows FAIR for technical reuse while recognizing that traditional knowledge requires CARE-aware and community-sensitive governance beyond technical openness (Carroll et al., 2020; Local Contexts, 2026; Wilkinson et al., 2016).

4 Results

4.1 Corpus composition and temporal profile

The frozen corpus contains 29 source records spanning 1915–2026. Twenty-four sources are marked high quality in the dataset registry, and all 34 claim records are marked verified. Seventeen primary-research sources dominate the registry, alongside government/legal, review, cultural/public, and other source classes.

The temporal distribution of indexed sources is shown in Figure 2.

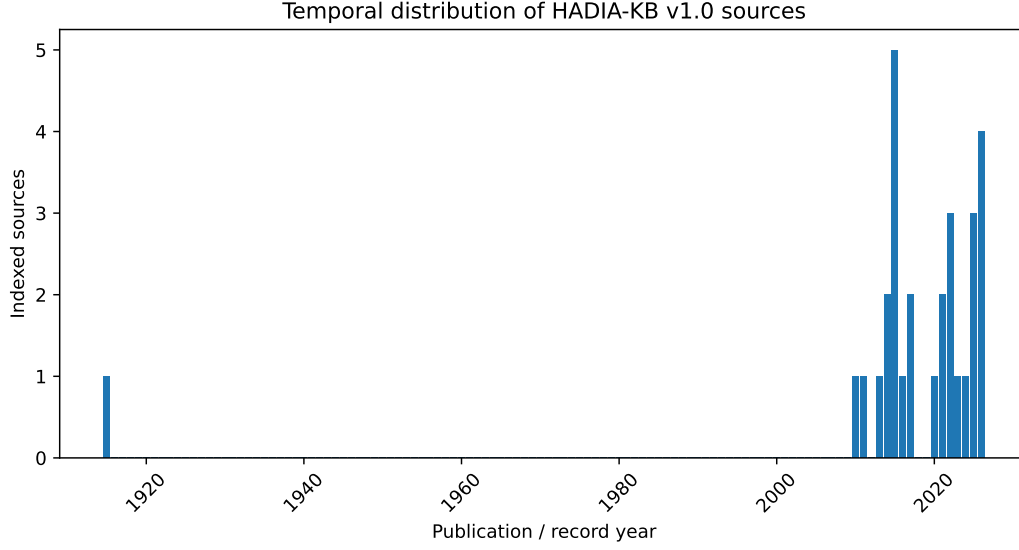


Figure 2: Temporal distribution of indexed source records in HADIA-KB v1.0.0.

4.2 Geographic asymmetry

Eleven source records are Jharkhand-scoped, yet only 12 of 34 claim records (35.3%) apply to Jharkhand. Seventeen claims apply to West Bengal, four to Odisha, and one is India-wide/other. Thus comparative claims outnumber Jharkhand claims by 22 to 12 (1.83:1), demonstrating that a Jharkhand-centered public knowledge portal must distinguish between focal-region evidence and comparative evidence.

Figure 3 shows the geographic distribution of claim-level evidence in the frozen corpus.

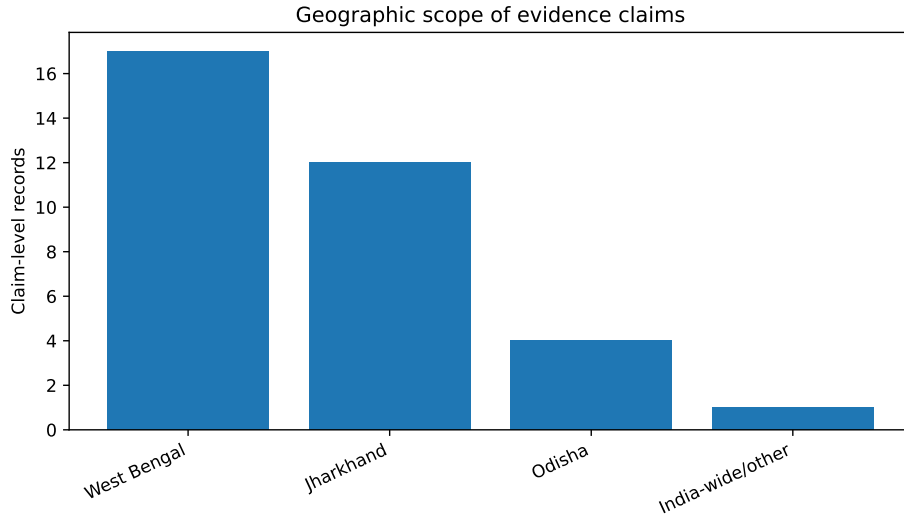


Figure 3: Geographic scope of claim-level evidence in the frozen corpus.

The corresponding source and claim counts by geographic scope are reported in Table 2.

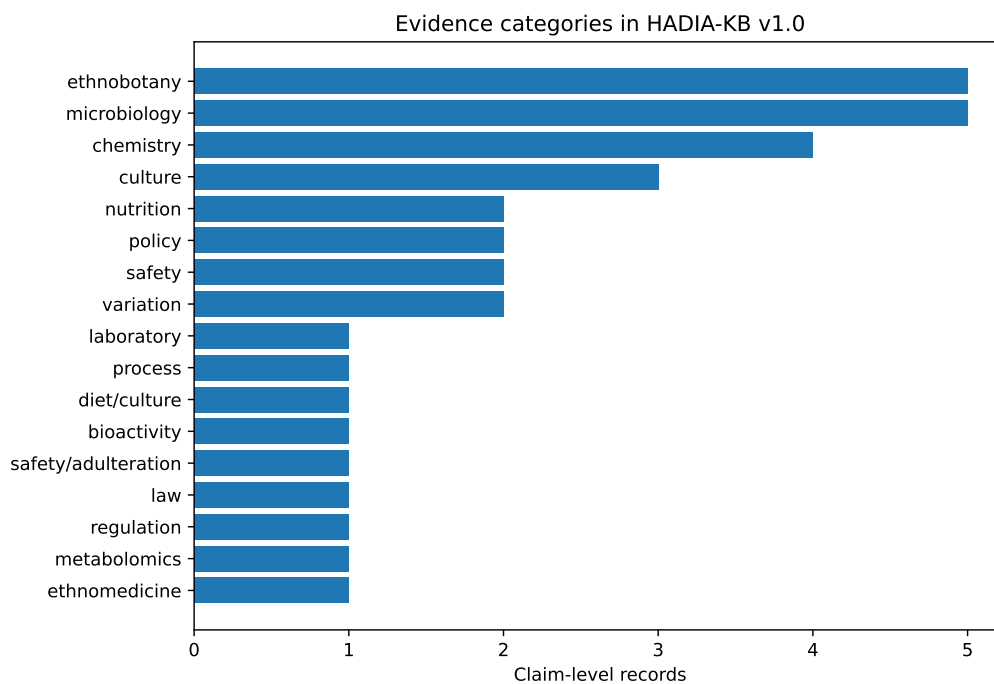
Table 2: Source and claim distribution by geographic scope.

Geographic scope	Sources	Claims	Claim share
Jharkhand	11	12	35.3
West Bengal	11	17	50.0
Odisha	3	4	11.8
India-wide/other	4	1	2.9

4.3 Thematic coverage

The 34 verified claims span 17 categories. Ethnobotany and microbiology contain five claims each, chemistry contains four, and culture contains three. Crucially, the frozen corpus contains no Jharkhand-specific microbiology, chemistry, nutrition, or metabolomics claim despite substantial comparative laboratory evidence from West Bengal and Odisha.

Figure 4 shows the distribution of claim categories represented in the frozen corpus.

**Figure 4:** Claim categories represented in HADIA-KB v1.0.0.

The interaction between claim category and geographic scope is visualized in Figure 5.

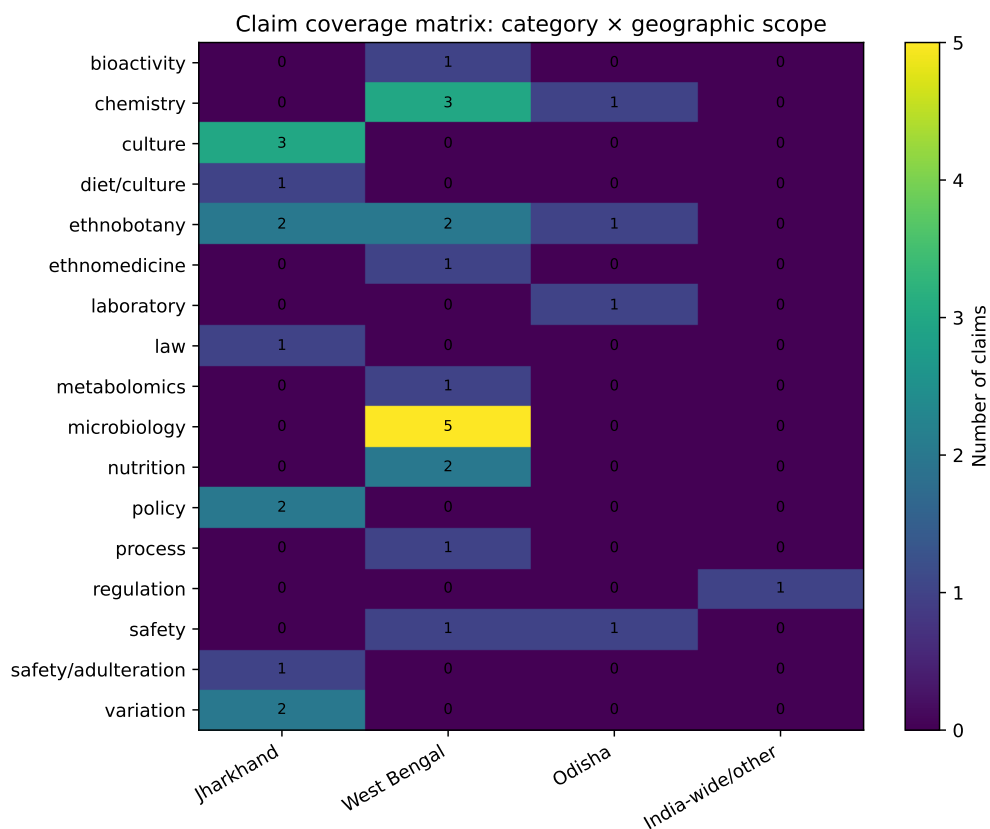


Figure 5: Coverage matrix of claim category by geographic scope. Zeros denote no claim in the frozen corpus, not absence of real-world knowledge.

Exact category counts, including Jharkhand-specific records, are reported in Table 3.

Table 3: Claim categories and Jharkhand-specific counts.

Claim category	All claims	Jharkhand claims
ethnobotany	5	2
microbiology	5	0
chemistry	4	0
culture	3	3
variation	2	2
policy	2	2
safety	2	0
nutrition	2	0
process	1	0
diet/culture	1	1
bioactivity	1	0
safety/adulteration	1	1
law	1	1
regulation	1	0
metabolomics	1	0
ethnomedicine	1	0
laboratory	1	0

4.4 Ethnobotanical evidence

The plant table contains 16 plant/lichen records. Five Jharkhand records are linked to the Ho Ranu evidence from West Singhbhum, while the comparative Bakhar records are explicitly scoped to West Bengal. The design therefore preserves the scientific distinction between “a plant has been reported in a starter somewhere” and “a plant is part of a universal Handia recipe.” This is consistent with prior ethnobotanical research emphasizing local variation in starter composition (A. J. Das & Deka, 2013; Duarah et al., 2023; S. Ghosh et al., 2022; Kujur & Kandir, 2015, 2016; Tanti et al., 2010).

The plant and lichen evidence registry is summarized in Table 4.

Table 4: Plant and lichen evidence records retained in HADIA-KB v1.0.0.

ID	Taxon as recorded	Part	Starter	Community	Scope	Source
HP0001	Woodfordia fruticosa (L.) Kurz	root	Ranu	Ho	West Singhbhum, Jharkhand	HS0002
HP0002	Ruellia tuberosa L.	root	Ranu	Ho	West Singhbhum, Jharkhand	HS0002
HP0003	Andrographis paniculata (Burm. f.) Wall. ex Nees	root	Ranu	Ho	West Singhbhum, Jharkhand	HS0002
HP0004	Dioscorea bulbifera L.	root	Ranu	Ho	West Singhbhum, Jharkhand	HS0002
HP0005	Madhuca longifolia var. latifolia	bark	Ranu	Ho	West Singhbhum, Jharkhand	HS0002
HP0006	Asparagus racemosus Willd.	root	Bakhar	Santal	West Bengal	HS0019
HP0007	Acorus calamus L.	rhizome	Bakhar	Santal	West Bengal	HS0019
HP0008	Ruellia tuberosa L.	root	Bakhar	Santal	West Bengal	HS0019
HP0009	Symplocos racemosa Roxb.	bark	Bakhar	Santal	West Bengal	HS0019
HP0010	Piper longum L.	dried fruit	Bakhar	Santal	West Bengal	HS0019
HP0011	Hemidesmus indicus R.Br.	root	Bakhar	Santal	West Bengal	HS0019
HP0012	Cassia senna L.	leaf	Bakhar	Santal	West Bengal	HS0019
HP0013	Polygala crotalarioides Buch.-Ham.	root	Bakhar	Santal	West Bengal	HS0019
HP0014	Ocimum basilicum L.	seed	Bakhar	Santal	West Bengal	HS0019
HP0015	Rubia cordifolia L.	root	Bakhar	Santal	West Bengal	HS0019
HP0016	Parmelia perlata (Huds.) Ach.	lichen	Bakhar	Santal	West Bengal	HS0019

4.5 Microbiology and quantitative measurements

All 12 microorganism records in the frozen release are comparative rather than Jharkhand-specific. They include lactic acid bacteria, yeasts, and other taxa identified by methods ranging from culture/screening to 16S rRNA characterization and PCR-DGGE. This pattern does not show that Jharkhand Handia lacks these organisms; it shows that the current corpus lacks Jharkhand-specific microbial evidence. The distinction is methodologically important given the demonstrated sensitivity of microbial-community descriptions to analytical technique (Bora et al., 2016; S. Das et al., 2022; K. Ghosh, Ray, Adak, Dey, et al., 2015; K. Ghosh, Ray, Adak, Halder, et al., 2015; K. Ghosh et al., 2021; Keisam et al., 2016; Keot et al., 2020; Ray et al., 2017).

The microorganism records and their reported identification methods are summarized in Table 5.

Table 5: Microorganism records and identification methods in the frozen corpus.

ID	Organism	Identification	Beverage	Scope	Source
HM0001	<i>Lactobacillus plantarum</i>	PCR-DGGE	Haria	West Bengal	HS0007
HM0002	<i>Lactobacillus brevis</i>	PCR-DGGE	Haria	West Bengal	HS0007
HM0003	<i>Lysinibacillus</i> sp.	PCR-DGGE	Haria	West Bengal	HS0007
HM0004	<i>Lysinibacillus fusiformis</i>	PCR-DGGE	Haria	West Bengal	HS0007
HM0005	uncultured <i>Bacillus</i> sp.	PCR-DGGE	Haria	West Bengal	HS0007
HM0006	<i>Lactobacillus fermentum</i> KKL1	culture + 16S rRNA	Haria	West Bengal	HS0006
HM0007	<i>Bifidobacterium</i> sp. MKK4	culture/screening	Haria	Bankura, West Bengal	HS0008
HM0008	<i>Pediococcus lolli</i> MKK21	culture/screening	Haria	Bankura, West Bengal	HS0008
HM0009	<i>Lactobacillus</i> sp. MKK37	culture/screening	Haria	Bankura, West Bengal	HS0008
HM0010	<i>Lactobacillus fermentum</i> TIU19	culture/characterization	Haria	West Bengal	HS0009
HM0011	<i>Saccharomyces cerevisiae</i>	microbial study	Haria	North Dinajpur, West Bengal	HS0024
HM0012	<i>Enterobacter</i> sp.	microbial study	Haria	North Dinajpur, West Bengal	HS0024

The 18 measurement records include alcohol, acidity, organic acids, phytase activity, malto-oligosaccharides, antioxidant-assay values, nutrients, and HR-LCMS compound counts. Because values come from distinct sample states and geographies, the database retains sample context and does not average them into a single “Handia composition.”

The quantitative measurement records retained in the frozen corpus are reported in Table 6.

Table 6: Quantitative measurement records in HADIA-KB v1.0.0.

ID	Analyte	Value	Unit	Context	Scope	Source
HME0001	alcohol_content	2-3	% v/v	consumable Haria	West Bengal	HS0004
HME0002	titratable_acidity	1.42	%	Haria	West Bengal	HS0004
HME0003	lactic_acid	17.63	mg/g	Haria	West Bengal	HS0007
HME0004	acetic_acid	0.18	mg/g	Haria	West Bengal	HS0007
HME0005	phytase_activity	18.93	U/g	day 4 Haria	West Bengal	HS0007
HME0006	maltotetrose	26.18	$\mu\text{g/g}$	fermented Haria	West Bengal	HS0005
HME0007	maltotriose	28.16	$\mu\text{g/g}$	fermented Haria	West Bengal	HS0005
HME0008	maltose	26.94	$\mu\text{g/g}$	fermented Haria	West Bengal	HS0005
HME0009	DPPH_radical_scavenging	82.54	%	day 4 fermented Haria	West Bengal	HS0005
HME0010	carbohydrate	55	mg/100 ml	raw Handia	West Bengal	HS0011
HME0011	glucose	10.2	mg/100 ml	raw Handia	West Bengal	HS0011
HME0012	protein	162	mg/100 ml	raw Handia	West Bengal	HS0011
HME0013	fat	5.6	mg/100 ml	raw Handia	West Bengal	HS0011
HME0014	alcohol_content	11.3	%	raw Handia	West Bengal	HS0011
HME0015	ascorbic_acid	15.40	mg/100 ml	homemade Haria	West Bengal	HS0019
HME0016	flavonoids	36.67	mg/100 ml	homemade Haria	West Bengal	HS0019
HME0017	HR-LCMS_compounds_detected	60	count	Haria	North Dinajpur, West Bengal	HS0024
HME0018	HR-LCMS_compounds_identified	37	count	Haria	North Dinajpur, West Bengal	HS0024

4.6 Contextual differences rather than forced contradictions

Two explicit difference records are retained. First, an alcohol value of 2–3% v/v for consumable Haria and an 11.3% value for raw Handia before dilution originate from different studies and sample states, so they are not treated as directly contradictory. Second, Ranu and Bakhar/Bhakar are preserved as geographically contextual starter names rather than forcibly collapsed.

These preserved contextual differences are summarized in Table 7.

Table 7: Contextual-difference records preserved in the frozen release.

ID	Topic	Relationship	Interpretation	Status
HCON0001	alcohol_content	contextual_difference	2-3% v/v refers to a consumable Haria study; 11.3% refers to raw Handia before dilution in a different study/population. These are not directly comparable.	resolved_as_context_difference
HCON0002	starter_name	terminological_geographic_variation	Ranu and Bakhar/Bhakar are source- and region-dependent starter names; HADIA-KB preserves rather than collapses them.	preserved_variation

4.7 Graph structure and source attribution

The evidence graph contains 125 nodes and 192 directed edges, with density 0.0124 and two weakly connected components. Claim attribution spans 24 sources. The claim-source HHI is 0.0484, Shannon entropy is 4.477 bits, and the corresponding effective source count is 22.27. These values show that claim attribution is distributed across many sources rather than dominated by one document, although the corpus remains small and curated.

Figure 6 presents the evidence-graph projection linking claims to supporting sources, categories, and reported names.

Evidence graph projection: claims linked to sources, categories, and names

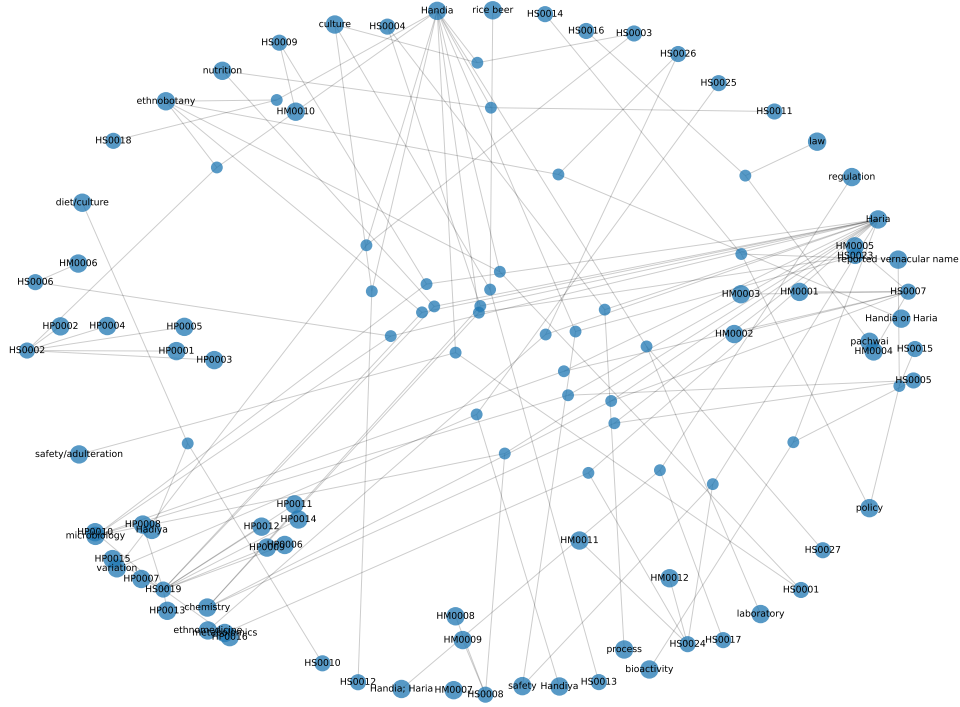


Figure 6: Projection of the evidence graph linking claims to supporting sources, categories, and reported names.

Computational integrity and structural metrics for the frozen release are summarized in Table 8.

Table 8: Reproducibility and structural audit of the frozen release.

Check/metric	Result	Interpretation
Verified claims	34/34	All claim records verified in frozen seed
High-quality sources	24/29	Source registry quality field
Graph nodes	125	Derived from relation table
Graph edges	192	Source-carrying directed relations
Graph density	0.0124	Directed density
Weak components	2	Graph connectivity
Claim-source HHI	0.0484	Lower values indicate less concentration
Effective source count	22.27	2^H , where H is Shannon entropy of claim attribution
Jharkhand claim share	35.3	

4.8 Documented knowledge gaps

The current Jharkhand corpus contains represented evidence for ethnobotany, culture, and policy, but zero claims for microbiology, chemistry, nutrition, and metabolomics. Safety/adulteration and legal evidence are sparse. These are research-priority indicators, not deficit judgments about communities or traditions.

The resulting Jharkhand documentation-gap profile is shown in Figure 7.

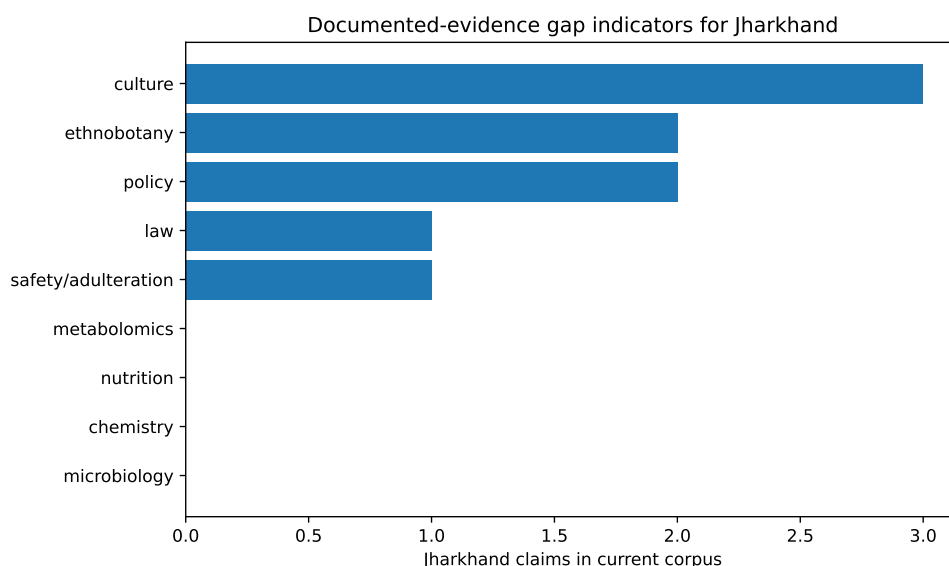


Figure 7: Documented-evidence gap indicators for Jharkhand in HADIA-KB v1.0.0.

The underlying documentation-gap indicators are reported in Table 9.

Table 9: Jharkhand documentation-gap indicators.

Topic	Jharkhand claims	Corpus interpretation
microbiology	0	Sparse in current corpus
chemistry	0	Sparse in current corpus
nutrition	0	Sparse in current corpus
safety/adulteration	1	Sparse in current corpus
metabolomics	0	Sparse in current corpus
ethnobotany	2	Represented in current corpus
culture	3	Represented in current corpus
policy	2	Represented in current corpus
law	1	Sparse in current corpus

5 Discussion

5.1 The central result is epistemic, not biochemical

The most important result of this study is not a new alcohol percentage, microorganism, or medicinal claim. It is the demonstration that published Handia/Haria knowledge is structurally heterogeneous. The frozen evidence landscape combines Jharkhand ethnobotany and culture with comparative laboratory evidence from neighboring regions. A conventional summary can accidentally flatten those boundaries; an evidence-linked model can keep them visible.

This matters because the global scientific literature on traditional fermentation is increasingly technically sophisticated. Metagenomic, high-throughput, metabolomic, and functional studies can reveal microbial diversity and biochemical potential (Alam et al., 2025; Bora et al., 2016; S. Das et al., 2019; D. Narzary et al., 2021; Nayak et al., 2026; Sha et al., 2017, 2018, 2019). Yet technical sophistication does not remove the need for provenance. In fact, it increases it: cross-study comparisons become less credible when geography, starter ecology, sample state, or assay context is lost.

5.2 Why “publicly documented knowledge” is a necessary boundary

HADIA-KB does not claim to contain Handia knowledge in its entirety. Oral, family-held, seasonal, sacred, gendered, community-governed, or unpublished knowledge may be absent from the public web. Treating a digital corpus as the total knowledge system would reproduce precisely the epistemic compression the database is designed to avoid. The distinction aligns with CARE, Local Contexts, intangible-heritage safeguards, and access/benefit-sharing frameworks (Carroll et al., 2020; Convention on Biological Diversity, 1992, 2010; Local Contexts, 2026; Russo Carroll et al., 2021; UNESCO, 2003).

For future community-engaged versions, technical openness should therefore be supplemented with community governance, attribution, and potentially access controls or Traditional Knowledge labels. The current public-evidence release is best interpreted as an index of documented evidence and documentation gaps, not as a substitute for community authority.

5.3 Implications for Jharkhand research

The strongest empirical gap is the absence of Jharkhand-specific microbiology, chemistry, nutrition, and metabolomics claims in the frozen corpus. Comparative work shows that such studies are feasible and scientifically informative (Alam et al., 2025; K. Ghosh, Ray, Adak, Dey, et al., 2015; K. Ghosh, Ray, Adak, Halder, et al., 2015; K. Ghosh et al., 2021; S. Ghosh et al., 2022; Nayak et al., 2026). A future Jharkhand program could therefore prioritize multi-district, community-governed sampling; repeated fermentation time series; starter-culture microbiome characterization; targeted and untargeted chemical profiling; standardized safety assays; and contextual sensory documentation. Importantly, such work should test heterogeneity rather

than presuppose a single authentic recipe.

5.4 Implications for global heritage visibility

UNESCO’s recognition of traditional sake-making foregrounds knowledge, skills, practitioners, transmission, regional practice, and cultural context rather than only the commercial beverage (UNESCO, 2024). This offers a useful conceptual comparison for Handia: global visibility need not begin with product standardization. It can begin with rigorous documentation, provenance, cultural attribution, research quality, responsible digital access, and explicit identification of what remains unknown. Geographical-indication frameworks similarly depend on demonstrated relationships between origin and characteristics or reputation, which require evidence rather than branding alone (World Intellectual Property Organization, 2026).

5.5 Reusability and interoperability

A practical strength of HADIA-KBis that the same evidence can be consumed by different audiences without changing the source-of-truth tables. Human users can explore the Streamlit portal; researchers can download CSV/XLSX; developers can use JSON/API outputs; semantic-web users can work with JSON-LD and RDF/Turtle; and graph researchers can use GraphML. Provenance and citation metadata are aligned with established data and software practices (Citation File Format Community, 2021; DataCite Metadata Working Group, 2024; Katz et al., 2021; RO-Crate Community, 2024; Smith et al., 2016; Wilkinson et al., 2016; World Wide Web Consortium, 2013).

6 Limitations

First, v1.0.0 is a curated public-evidence corpus, not an exhaustive systematic review of every web page, publication, thesis, archive, or oral tradition. Second, database verification establishes traceability to indexed sources; it does not independently reproduce laboratory experiments or validate traditional medicinal claims. Third, several source records are public or institutional descriptions rather than peer-reviewed primary science, and source type must therefore remain visible during reuse. Fourth, the knowledge-gap indicators are corpus statistics, not estimates of true knowledge prevalence. Fifth, canonical naming is a computational convenience and should not erase local terminology. Sixth, the corpus is English-dominant and will underrepresent knowledge documented in local languages or inaccessible archives. Finally, the present work does not recruit participants or collect new biological samples, so it cannot resolve the Jharkhand laboratory gaps it identifies.

7 Conclusion

HADIA-KB demonstrates a different way to digitize traditional food knowledge: preserve evidence boundaries before seeking synthesis. In the frozen v1.0.0 release, the literature is demonstrably asymmetric: Jharkhand is central culturally and ethnobotanically, while much of the detailed laboratory evidence comes from comparative regional studies. The claim-level data model prevents those contexts from being silently merged, and the graph, gap indicators, and downloadable formats turn the corpus into reusable research infrastructure. The result is neither a universal Handia recipe nor a claim to own community knowledge. It is an auditable map of documented evidence, its provenance, its limits, and its unanswered questions. That foundation can support better future fieldwork, laboratory science, heritage documentation, policy analysis, and responsible international visibility.

Data Availability

The HADIA-KB v1.0.0 software and frozen evidence release are available at <https://github.com/Arithmetic-Power-Geometry/HADIA-KB> and archived at <https://doi.org/10.5281/zenodo.22132285>. The repository contains CSV, XLSX, JSON, JSON-LD, RDF/Turtle, GraphML, PostgreSQL schema, API code, Streamlit software, validation tests, and citation metadata.

Ethics and Responsible Use

No new human participants, interviews, or biological samples were used in this study. The analysis is based on publicly documented sources and the attached evidence dataset. Public availability is not interpreted as community ownership transfer. Future incorporation of community-held knowledge should require appropriate consent, governance, attribution, and benefit-sharing procedures consistent with relevant ethical and legal frameworks.

Consent to participate

Not applicable.

Consent to publish

Not applicable.

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Conflict of Interest

The author declares no conflict of interest.

Author Contributions

Mohammad Amir Khusru Akhtar: Conceptualization, methodology, data curation, software, formal analysis, visualization, validation, writing–original draft, writing–review and editing, and project administration.

A Source-class composition

Figure 8 shows the source-class composition of the frozen registry.

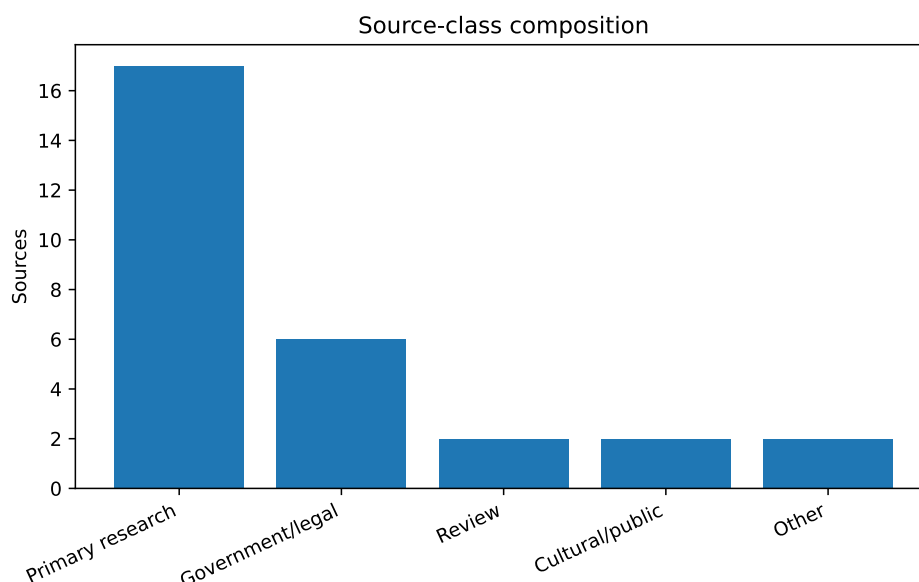


Figure 8: Simplified source-class composition of the frozen HADIA-KB registry.

B Citation coverage of the evidence registry

The manuscript’s direct Handia/Haria evidence discussion cites the source families represented in the frozen registry, including Jharkhand ethnobotanical, nutritional, cultural, policy, legal, West Bengal laboratory, Odisha laboratory, review, public-documentation, repository, and regulatory records (Alam et al., 2025; Bharathidasan University, 2010; Bisai et al., 2023; S. Das et al., 2022; District Administration Khunti, 2026; Food Safety and Standards Authority of India, 2025; K. Ghosh, Ray, Adak, Dey, et al., 2015; K. Ghosh, Ray, Adak, Halder, et al., 2015; K. Ghosh et al., 2014, 2021; S. Ghosh et al., 2022; Ghosh-Jerath et al., 2015; Government of Jharkhand, 2020, 2021, 2026; Hembrom et al., 2022; India Code, 1915; Kuiry, 2025; Kujur & Kandir, 2015,

2016; Kumar & Kumari, 2011; Nandi, 2024; National Library of Medicine, 2015; Nayak et al., 2026; Panda & Bastia, 2013; Panda et al., 2014; Ray et al., 2017; Sahoo, 2017; The Locavore and Dipatoli community, 2026). The broader methodological literature cited throughout the paper situates these records within Indian fermented-food science, evidence synthesis, digital provenance, open research, and responsible traditional-knowledge governance.

References

- Achaya, K. T. (2003). *The story of our food*. Universities Press.
- Alam, R., Mazumder, J. A., Das, S., & Das Mohapatra, P. K. (2025). HPLC-based metabolite profiling, antioxidant activity and microbial study of haria from the north dinajpur district of west bengal, india. *Bioresource Technology Reports*, 29, 102020. <https://doi.org/10.1016/j.biteb.2025.102020>
- Anupma, A., Pradhan, P., Sha, S. P., & Tamang, J. P. (2018). Traditional skill of ethnic people of the eastern himalayas and north east india in preserving microbiota as dry amylolytic starters. *Indian Journal of Traditional Knowledge*, 17(1), 184–190.
- Anupma, A., & Tamang, J. P. (2020). Diversity of filamentous fungi isolated from some amylase and alcohol-producing starters of india. *Frontiers in Microbiology*, 11, 905.
- Barman, P., Roy, K., & Sahu, R. K. (2026). Systematic review on traditional fermented rice beverages of assam. *Next Research*, 4, 101241. <https://doi.org/10.1016/j.nexres.2025.101241>
- Basappa, S. C., Somashekar, D., Agrawal, R., Suma, K., & Bharathi, K. (1997). Nutritional composition of fermented ragi (chhang) by phab and defined starter cultures as compared to unfermented ragi. *International Journal of Food Sciences and Nutrition*, 48, 313–319.
- Batra, L. R., & Millner, P. D. (1974). Some asian fermented foods and beverages and associated fungi. *Mycologia*, 66, 942–950.
- Bharathidasan University. (2010). *Rice and other cereals based beverages*. Retrieved August 27, 2026, from <https://www.bdu.ac.in/schools/biotechnology-and-genetic-engineering/biotechnology/sekardb/pdf/beverage/2.pdf>
- Bisai, S., Dutta, S., & Das Mohapatra, P. K. (2023). Traditional food consumption pattern and nutritional status of oraons: An asian indian indigenous community. *Frontiers in Sustainable Food Systems*, 7, 969264. <https://doi.org/10.3389/fsufs.2023.969264>
- Blandino, A., Al-Aseeri, M. E., Pandiella, S. S., Cantero, D., & Webb, C. (2003). Cereal-based fermented foods and beverages. *Food Research International*, 36, 527–543. [https://doi.org/10.1016/S0963-9969\(03\)00009-7](https://doi.org/10.1016/S0963-9969(03)00009-7)
- Bora, S. S., Keot, J., Das, S., Sarma, K., & Barooah, M. (2016). Metagenomics analysis of microbial communities associated with a traditional rice wine starter culture (xaj-pitha) of assam, india. *3 Biotech*, 6(2), 153. <https://doi.org/10.1007/s13205-016-0471-1>
- Carroll, S. R., Garba, I., Figueroa-Rodríguez, O. L., Holbrook, J., Lovett, R., Materechera, S., Parsons, M., Raseroka, K., Rodriguez-Lonebear, D., Rowe, R., Sara, R., Walker, J. D.,

- Anderson, J., & Hudson, M. (2020). The care principles for indigenous data governance. *Data Science Journal*, 19, 43. <https://doi.org/10.5334/dsj-2020-043>
- Citation File Format Community. (2021). *Citation file format 1.2.0*. Retrieved August 27, 2026, from <https://citation-file-format.github.io/>
- Convention on Biological Diversity. (1992). *Convention on biological diversity*. Retrieved August 27, 2026, from <https://www.cbd.int/convention/text/>
- Convention on Biological Diversity. (2010). *Nagoya protocol on access and benefit-sharing*. Retrieved August 27, 2026, from <https://www.cbd.int/abs/>
- Daba, G. M., Mostafa, F. A., & Elkhateeb, W. A. (2021). The ancient koji mold *aspergillus oryzae* as a modern biotechnological tool. *Bioresources and Bioprocessing*, 8, 52.
- Das, A., Raychaudhuri, U., & Chakraborty, R. (2012). Cereal based functional food of indian subcontinent: A review. *Journal of Food Science and Technology*, 49(6), 665–672.
- Das, A. J., & Deka, S. C. (2013). Ethno medicinal value of various plants used in the preparation of traditional rice beer by different tribes of assam, india. *Drug Invention Today*, 5(4), 335–341. <https://doi.org/10.1016/j.dit.2013.09.002>
- Das, G., Patra, J. K., Singdevsachan, S. K., Gouda, S., & Shin, H. S. (2016). Diversity of traditional and fermented foods of the seven sister states of india and their nutritional and nutraceutical potential: A review. *Frontiers in Life Science*, 9(4), 292–312.
- Das, S., Deb, D., Adak, A., & Khan, M. R. (2019). Exploring the microbiota and metabolites of traditional rice beer varieties of assam and their functionalities. *3 Biotech*, 9(5), 174. <https://doi.org/10.1007/s13205-019-1702-z>
- Das, S., Vishakha, K., Banerjee, S., et al. (2022). A novel probiotic strain of *lactobacillus fermentum* tiu19 isolated from haria beer showing both in vitro antibacterial and antibiofilm properties upon two multi resistant uro-pathogen strains. *Current Research in Microbial Sciences*, 3, 100150. <https://doi.org/10.1016/j.crmicr.2022.100150>
- DataCite Metadata Working Group. (2024). *Datacite metadata schema documentation for the publication and citation of research data and other research outputs, version 4.6*. Retrieved August 27, 2026, from <https://schema.datacite.org/meta/kernel-4.6/>
- District Administration Khunti. (2026). *Culture & heritage*. Retrieved August 27, 2026, from <https://khunti.nic.in/culture-heritage/>
- Duarah, R., Kalita, P., & Mishra, A. (2023). Medicinal plants used in rice beer starter culture by different tribes in assam: An ethnobotanical survey. *International Journal of Pharmaceutical Sciences and Research*, 14(6), 3012–3027. [https://doi.org/10.13040/IJPSR.0975-8232.14\(6\).3012-27](https://doi.org/10.13040/IJPSR.0975-8232.14(6).3012-27)
- Dublin Core Metadata Initiative. (2020). *Dcmi metadata terms*. Retrieved August 27, 2026, from <https://www.dublincore.org/specifications/dublin-core/dcmi-terms/>
- Ehrlinger, L., & Wöß, W. (2016). Towards a definition of knowledge graphs. *SEMANTiCS Posters and Demos*.
- Food Safety and Standards Authority of India. (2025). *Food safety and standards (alcoholic beverages) first amendment regulations, 2025*. Retrieved August 27, 2026, from <https://>

[// fssai . gov . in / upload / uploadfiles / files / Food % 20Safety % 20and % 20Standards __ Alcoholic%20Beverages _First%20Amendment%20Regulations%202025.pdf](https://fssai.gov.in/upload/uploadfiles/files/Food%20Safety%20and%20Standards__Alcoholic%20Beverages_First%20Amendment%20Regulations%202025.pdf)

- Ghosh, K., Adak, A., Halder, S. K., & Mondal, K. C. (2021). Physicochemical characteristics and lactic acid bacterial diversity of an ethnic rice fermented mild alcoholic beverage, haria. *Frontiers in Sustainable Food Systems*, 5, 680738. <https://doi.org/10.3389/fsufs.2021.680738>
- Ghosh, K., Maity, C., Adak, A., Halder, S. K., Jana, A., Das, A., Parua, S., Das Mohapatra, P. K., Pati, B. R., & Mondal, K. C. (2014). Ethnic preparation of haria, a rice-based fermented beverage, in the province of lateritic west bengal, india. *Ethnobotany Research and Applications*, 12, 39–49. <https://ethnobotanyjournal.org/index.php/era/article/view/811>
- Ghosh, K., Ray, M., Adak, A., Dey, P., Halder, S. K., Das, A., Jana, A., Parua, S., Vágvölgyi, C., Das Mohapatra, P. K., Pati, B. R., & Mondal, K. C. (2015). Microbial, saccharifying and antioxidant properties of an indian rice based fermented beverage. *Food Chemistry*, 168, 196–202. <https://doi.org/10.1016/j.foodchem.2014.07.042>
- Ghosh, K., Ray, M., Adak, A., Halder, S. K., Das, A., Jana, A., Parua, S., Vágvölgyi, C., Das Mohapatra, P. K., Pati, B. R., & Mondal, K. C. (2015). Role of probiotic lactobacillus fermentum kkl1 in the preparation of a rice based fermented beverage. *Bioresource Technology*, 188, 161–168. <https://doi.org/10.1016/j.biortech.2015.01.130>
- Ghosh, S., Sen, S. K., & Mondal, S. (2022). Ethnobotanical perspectives of bakhar: An indigenous starter culture used to prepare traditionally fermented rice beverage in rural west bengal, india. *Journal of Ethnic Foods*, 9, 26. <https://doi.org/10.1186/s42779-022-00143-6>
- Ghosh-Jerath, S., Singh, A., Kamboj, P., Goldberg, G., & Magsumbol, M. S. (2015). Traditional knowledge and nutritive value of indigenous foods in the oraon tribal community of jharkhand: An exploratory cross-sectional study. *Ecology of Food and Nutrition*, 54(5), 493–519. <https://doi.org/10.1080/03670244.2015.1017758>
- Global Indigenous Data Alliance. (2019). *Care principles for indigenous data governance*. Retrieved August 27, 2026, from <https://www.gida-global.org/careprinciples>
- Goel, A., Halami, P. M., & Tamang, J. P. (2020). Genome analysis of lactobacillus plantarum isolated from some indian fermented foods for bacteriocin production and probiotic marker genes. *Frontiers in Microbiology*, 11, 40.
- Gogoi, G. (2021). Traditional knowledge on preparation of starter culture cakes and rice-beers by chaodang community of upper assam, india. *Emergent Life Sciences Research*, 7(1), 63–75. <https://doi.org/10.31783/elsr.2021.716375>
- Government of Jharkhand. (2020). *Rural development department review: Phulo jhano / mission navjeevan*. Retrieved August 27, 2026, from <https://cm.jharkhand.gov.in/node/14041>
- Government of Jharkhand. (2021). *Phulo jhano aashirwad campaign interaction*. Retrieved August 27, 2026, from <https://cm.jharkhand.gov.in/node/13913>
- Government of Jharkhand. (2026). *Sarhul*. Retrieved August 27, 2026, from <https://cm.jharkhand.gov.in/sarhul>
- Guha, R. V., Brickley, D., & Macbeth, S. (2016). Schema.org: Evolution of structured data on the web. *Communications of the ACM*, 59(2), 44–51.

- Handa, S., & Sharma, N. (2016). In vitro study of probiotic properties of lactobacillus plantarum f22 isolated from chhang: A traditional fermented beverage of himachal pradesh, india. *Journal of Genetic Engineering and Biotechnology*, 14(1), 91–97. <https://doi.org/10.1016/j.jgeb.2016.08.001>
- Hembrom, S., Lal, S., & Kumar, S. (2022). The microbiology and traditional state of fermented beverage handia: A review. *Research Journal of Agricultural Sciences*, 13.
- Hogan, A., Blomqvist, E., Cochez, M., DAmato, C., Melo, G. d., Gutierrez, C., et al. (2021). Knowledge graphs. *ACM Computing Surveys*, 54(4), 1–37.
- India Code. (1915). *The excise law of bihar & jharkhand, 1915*. Retrieved August 27, 2026, from https://www.indiacode.nic.in/handle/123456789/6054?sam_handle=%2F1000
- Jeyaram, K., Singh, W. M., Capece, A., & Romano, P. (2008). Molecular identification of yeast species associated with hamei: A traditional starter used for rice wine production in manipur, india. *International Journal of Food Microbiology*, 124, 115–125.
- Jeyaram, K., Tamang, J. P., Capece, A., & Romano, P. (2011). Geographical markers for saccharomyces cerevisiae strains with similar technological origins domesticated for rice-based ethnic fermented beverages production in north east india. *Antonie van Leeuwenhoek*, 100(4), 569–578.
- Katz, D. S., Hong, N. P. C., Clark, T., Muench, A., Stall, S., Bouquin, D., et al. (2021). Recognizing the value of software: A software citation guide. *F1000Research*, 9, 1257.
- Keisam, S., Romi, W., Ahmed, G., & Jeyaram, K. (2016). Quantifying the biases in metagenome mining for realistic assessment of microbial ecology of naturally fermented foods. *Scientific Reports*, 6.
- Keisam, S., Tuikhar, N., Ahmed, G., & Jeyaram, K. (2019). Toxigenic and pathogenic potential of enteric bacterial pathogens prevalent in traditional fermented foods marketed in northeast india. *International Journal of Food Microbiology*, 296, 21–30.
- Keot, J., Bora, S. S., Das, K. R., & Barooah, M. (2020). Assessment of microbial quality and health risks associated with traditional rice wine starter xaj-pitha of assam, india: A step towards defined and controlled fermentation. *3 Biotech*, 10(2).
- Kuiri, H. K. (2025). Brewing belief: The cultural and political life of hadia and sarhul in jharkhand. *Journal of South Asian Exchanges*, 2(2). <https://doi.org/10.21659/jsae/v2n2/v2n212>
- Kujur, S., & Kandir, K. (2015). Studies on ethnomedicinal plants used in rice-beer (handia) by 'ho' tribe of jharkhand. *International Journal for Exchange of Knowledge*, 2(1), 104–108. <https://jbb.jharkhand.gov.in/wp-content/uploads/2024/12/46.STUDIES-ON-ETHNOMEDICINAL-PLANTS-USED-IN-RICE-BEER-Handia-BY-%E2%80%98HO-TRIBE-OF-JHARKHAND.pdf>
- Kujur, S., & Kandir, K. (2016). Ethnobotany of starter culture (ranu) used in production of rice-beer (handia) by oraon tribes of khunti district of jharkhand. *Biospectra*. <https://mset-biospectra.org/2016/09/ethnobotany-of-starter-culture-ranu-used-in-production-of-rice-beer-handia-by-oraon-tribes-of-khunti-district-of-jharkhand/>

- Kumar, S., & Kumari, B. (2011). A check list of medicinal plants used in making rice beer (handia) in jharkhand. *Biospectra*. <https://mset-biospectra.org/2012/06/a-check-list-of-medicinal-plants-used-in-making-rice-beer-handia-in-jharkhand/>
- Leeuwendaal, N. K., Stanton, C., OToole, P. W., & Beresford, T. P. (2022). Fermented foods, health and the gut microbiome. *Nutrients*, *14*, 1527.
- Linares, D. M., Gómez, C., Renes, E., Fresno, J. M., Tornadijo, M. E., Ross, R. P., & Stanton, C. (2017). Lactic acid bacteria and bifidobacteria with potential to design natural biofunctional health-promoting dairy foods. *Frontiers in Microbiology*, *8*, 846.
- Local Contexts. (2026). *Traditional knowledge labels*. Retrieved August 27, 2026, from <https://localcontexts.org/labels/traditional-knowledge-labels/>
- Loying, R., et al. (2024). Rice-based alcoholic fermented beverages of north-east india: Insight into ethnic preparation, microbial intervention, ethnobotany, and health benefits. *Journal of Food Biochemistry*, *2024*, 7769743. <https://doi.org/10.1155/2024/7769743>
- Marco, M. L., Heeney, D., Binda, S., Cifelli, C. J., Cotter, P. D., Foligné, B., et al. (2017). Health benefits of fermented foods: Microbiota and beyond. *Current Opinion in Biotechnology*, *44*, 94–102.
- Moreau, L., Missier, P., et al. (2013). Prov-dm: The prov data model. *W3C Recommendation*.
- Mukherjee, S. K., Albury, C. S., Pederson, A. G., & Steinkraus, K. H. (1965). Role of leuconostoc mesenteroides in leavening the batter of idli, a fermented food of india. *Applied Microbiology*, *13*(2), 227–231.
- Nandi, P. (2024). A review on handia: A traditional drink of tribals. *International Journal of Food and Nutritional Sciences*, *13*.
- Narzary, D., Boro, N., Borah, A., et al. (2021). Community structure and metabolic potentials of the traditional rice beer starter 'emao'. *Scientific Reports*, *11*, 14628. <https://doi.org/10.1038/s41598-021-94059-x>
- Narzary, Y., Brahma, J., Brahma, C., & Das, S. (2016). A study on indigenous fermented foods and beverages of kokrajhar, assam, india. *Journal of Ethnic Foods*, *3*(4), 284–291.
- Nath, N., Ghosh, S., Rahaman, L., et al. (2016). Community-wise evaluation of rice beer prepared by some ethnic tribes of tripura. *Journal of Ethnic Foods*, *3*(4), 251–256. <https://doi.org/10.1016/j.jef.2016.12.001>
- Nath, N., Ghosh, S., Rahaman, L., Kaipeng, D. L., & Sharma, B. K. (2019). An overview of traditional rice beer of north-east india: Ethnic preparation, challenges and prospects. *Indian Journal of Traditional Knowledge*, *18*.
- National Library of Medicine. (2015). *Pubmed record: Microbial, saccharifying and antioxidant properties of an indian rice based fermented beverage*. Retrieved August 27, 2026, from <https://pubmed.ncbi.nlm.nih.gov/25172700/>
- Nayak, D., Rana, S., Singha, T. S., Rai, M., Panda, J., & Mohanta, Y. K. (2026). Physicochemical, antibacterial and antioxidant evaluation of cereal-based ethnic fermented handia: An exploration for its food quality and health benefits from mayurbhanj district in odisha. *Food and Humanity*, *7*, 101348. <https://doi.org/10.1016/j.foohum.2026.101348>

- Nosek, B. A., Alter, G., Banks, G. C., Borsboom, D., Bowman, S. D., Breckler, S. J., et al. (2015). Promoting an open research culture. *Science*, 348(6242), 1422–1425.
- Page, M. J., McKenzie, J. E., Bossuyt, P. M., Boutron, I., Hoffmann, T. C., Mulrow, C. D., et al. (2021). The prisma 2020 statement: An updated guideline for reporting systematic reviews. *BMJ*, 372, n71. <https://doi.org/10.1136/bmj.n71>
- Panda, S. K., & Bastia, A. K. (2013). Antimicrobial efficacy of potential plants used in the indigenous preparation of traditional rice beverage handia. *International Journal of Phytomedicine*, 5.
- Panda, S. K., Bastia, A. K., & Sahoo, G. (2014). Process characteristics and nutritional evaluation of handia: A cereal based ethnic fermented food from odisha. *Indian Journal of Traditional Knowledge*, 13, 149–156.
- Payyappallimana, U., & Venkatasubramanian, P. (2016). Exploring ayurvedic knowledge on food and health for providing innovative solutions to contemporary healthcare. *Frontiers in Public Health*, 4, 57.
- Peng, R. D. (2011). Reproducible research in computational science. *Science*, 334(6060), 1226–1227.
- Pradhan, P., & Tamang, J. P. (2019). Phenotypic and genotypic identification of bacteria isolated from traditionally prepared dry starters of the eastern himalayas. *Frontiers in Microbiology*, 10, 2526.
- Pradhan, P., & Tamang, J. P. (2021). Probiotic properties of lactic acid bacteria isolated from traditionally prepared dry starters of the eastern himalayas. *World Journal of Microbiology and Biotechnology*, 37, 7.
- Prakash, O. (1961). *Food and drinks in ancient india*. Munshi Ram Manoharlal.
- Ray, M., Hor, P. K., Singh, S. N., & Mondal, K. C. (2017). Screening of health beneficial microbes with potential probiotic characteristics from the traditional rice-based alcoholic beverage, haria. *Acta Biologica Szegediensis*, 61, 39–45. <https://www.abs.bibl.u-szeged.hu/index.php/abs/article/view/2913>
- RO-Crate Community. (2024). *Ro-crate specification 1.2*. Retrieved August 27, 2026, from <https://www.researchobject.org/ro-crate/specification/1.2/introduction.html>
- Russo Carroll, S., Herczog, E., Hudson, M., Russell, K., & Stall, S. (2021). Operationalizing the care and fair principles for indigenous data futures. *Scientific Data*, 8, 108.
- Sahoo, T. K. (2017). Ethnobotany of bakhar used to prepare rice beer (haria) in paschim medinipur, west bengal, india. *Indian Journal of Biological Sciences*. <https://ir.vidyasagar.ac.in/handle/123456789/5186>
- Saikia, B., Ali, M. S., Gogoi, S. H., & Nath, P. D. (2024). Isolation and characterization of the mycofloral diversity in traditional assamese alcoholic fermentation from india. *Asian Journal of Dairy and Food Research*, 43(1), 104–110. <https://doi.org/10.18805/ajdfr.DR-1829>
- Sandve, G. K., Nekrutenko, A., Taylor, J., & Hovig, E. (2013). Ten simple rules for reproducible computational research. *PLoS Computational Biology*, 9(10), e1003285.

- Sanjukta, S., & Rai, A. K. (2016). Production of bioactive peptides during soybean fermentation and their potential health benefits. *Trends in Food Science & Technology*, 50, 1–10.
- Satish Kumar, R., Kanmani, P., Yuvaraj, N., Paari, K. A., Pattukumar, V., & Arul, V. (2013). Traditional indian fermented foods: A rich source of lactic acid bacteria. *International Journal of Food Sciences and Nutrition*, 64(4), 415–428. <https://doi.org/10.3109/09637486.2012.746288>
- Sha, S. P., Anupma, A., Pradhan, P., Prasad, G. S., & Tamang, J. P. (2016). Identification of yeasts by pcr-mediated dgge in marcha, an ethnic amyolytic starter of india. *Journal of Ethnic Foods*, 3, 292–296.
- Sha, S. P., Jani, K., Sharma, A., Anupma, A., Pradhan, P., Shouche, Y., et al. (2017). Analysis of bacterial and fungal communities in marcha and thiat, traditionally prepared amyolytic starters of india. *Scientific Reports*, 7, 10967.
- Sha, S. P., Suryavanshi, M. S., Jani, K., Sharma, A., Shouche, Y., & Tamang, J. P. (2018). Diversity of yeasts and molds by culture-dependent and culture-independent methods for mycobiome surveillance of traditionally prepared dried starters for indian alcoholic beverages. *Frontiers in Microbiology*, 9, 2237.
- Sha, S. P., Suryavanshi, M. S., & Tamang, J. P. (2019). Mycobiome diversity in traditionally prepared starters for alcoholic beverages in india by high-throughput sequencing. *Frontiers in Microbiology*, 10, 348.
- Smith, A. M., Katz, D. S., Niemeyer, K. E., & Group, F. S. C. W. (2016). Software citation principles. *PeerJ Computer Science*, 2, e86.
- Soiland-Reyes, S., Sefton, P., Crosas, M., Castro, L., Coppens, F., Fernández, J. M., et al. (2022). Packaging research artefacts with ro-crate. *Data Science*, 5, 97–138.
- Soni, S. K., & Sandhu, D. K. (1990). Indian fermented foods: Microbiological and biochemical aspects. *Indian Journal of Microbiology*, 30, 130–157.
- Swain, M. R., Anandharaj, M., Ray, R. C., & Parveen Rani, R. (2014). Fermented fruits and vegetables of asia: A potential source of probiotics. *Biotechnology Research International*, 2014, 250424. <https://doi.org/10.1155/2014/250424>
- Tamang, J. P., & Thapa, S. (2006). Fermentation dynamics during production of bhaati jaanr, a traditional fermented rice beverage of the eastern himalayas. *Food Biotechnology*, 20, 251–261.
- Tamang, J. P. (2010). *Himalayan fermented foods: Microbiology, nutrition, and ethnic values*. CRC Press.
- Tamang, J. P. (2020). History and culture of indian ethnic fermented foods and beverages. In *Ethnic fermented foods and alcoholic beverages of india: Science history and culture* (pp. 1–40). Springer Nature.
- Tamang, J. P. (2022). Ethno-microbiology of ethnic indian fermented foods and alcoholic beverages. *Journal of Applied Microbiology*, 133(1), 145–161. <https://doi.org/10.1111/jam.15382>

- Tamang, J. P., Cotter, P. D., Endo, A., Han, N. S., Kort, R., Liu, S.-Q., et al. (2020). Fermented foods in a global age: East meets west. *Comprehensive Reviews in Food Science and Food Safety*, 19, 184–217.
- Tamang, J. P., Dewan, S., Tamang, B., Rai, A., Schillinger, U., & Holzapfel, W. H. (2007). Lactic acid bacteria in hamei and marcha of north east india. *Indian Journal of Microbiology*, 47, 119–125.
- Tamang, J. P., Holzapfel, W. H., & Watanabe, K. (2016). Diversity of microorganisms in global fermented foods and beverages. *Frontiers in Microbiology*, 7, 377.
- Tamang, J. P., Jeyaram, K., Rai, A. K., & Mukherjee, P. K. (2021). Diversity of beneficial microorganisms and their functionalities in community-specific ethnic fermented foods of the eastern himalayas. *Food Research International*, 148, 110633.
- Tamang, J. P., Sarkar, P. K., & Hesseltine, C. W. (1988). Traditional fermented foods and beverages of darjeeling and sikkim: A review. *Journal of the Science of Food and Agriculture*, 44, 375–385. <https://doi.org/10.1002/jsfa.2740440410>
- Tamang, J. P., Tamang, B., Thapa, S., Dewan, S., Tamang, B. M., Yonzan, H., et al. (2012). Microorganisms and nutritional value of ethnic fermented foods and alcoholic beverages of north east india. *Indian Journal of Traditional Knowledge*, 11, 7–25.
- Tamang, J. P., Thapa, S., Tamang, N., & Rai, B. (1996). Indigenous fermented food beverages of darjeeling hills and sikkim: Process and product characterization. *Journal of Hill Research*, 9(2), 401–411.
- Tanti, B., Gurung, L., Sarma, H., & Buragohain, A. (2010). Ethnobotany of starter cultures used in alcohol fermentation by a few ethnic tribes of northeast india. *Indian Journal of Traditional Knowledge*, 9(3), 463–466.
- Thakur, N., Saris, P. E. J., & Bhalla, T. C. (2015). Microorganisms associated with amylolytic starters and traditional fermented alcoholic beverages of north western himalayas in india. *Food Bioscience*, 11, 92–96. <https://doi.org/10.1016/j.fbio.2015.05.002>
- Thapa, S., & Tamang, J. P. (2004). Product characterization of kodo ko jaanr: Fermented finger millet beverage of the himalayas. *Food Microbiology*, 21, 617–622.
- Thapa, S., & Tamang, J. P. (2006). Microbiological and physico-chemical changes during fermentation of kodo ko jaanr, a traditional alcoholic beverage of the darjeeling hills and sikkim. *Indian Journal of Microbiology*, 46(4), 333–341.
- The Locavore and Dipatoli community. (2026). *Handiya*. Retrieved August 27, 2026, from <https://thelocavore.in/2026/04/21/handiya/>
- Tsuyoshi, N., Fudou, R., Yamanaka, S., Kozaki, M., Tamang, N., Thapa, S., et al. (2005). Identification of yeast strains isolated from marcha in sikkim, a microbial starter for amylolytic fermentation. *International Journal of Food Microbiology*, 99, 135–146.
- UNESCO. (2003). *Convention for the safeguarding of the intangible cultural heritage*. Retrieved August 27, 2026, from <https://ich.unesco.org/en/convention>
- UNESCO. (2024). *Traditional knowledge and skills of sake-making with koji mold in japan*. Retrieved August 27, 2026, from <https://ich.unesco.org/en/RL/traditional-knowledge-and-skills-of-sake-making-with-koji-mold-in-japan-01977>

- Wilkinson, M. D., Dumontier, M., Aalbersberg, I. J., Appleton, G., Axton, M., Baak, A., et al. (2016). The fair guiding principles for scientific data management and stewardship. *Scientific Data*, 3, 160018. <https://doi.org/10.1038/sdata.2016.18>
- World Intellectual Property Organization. (2026). *Geographical indications*. Retrieved August 27, 2026, from <https://www.wipo.int/en/web/geographical-indications>
- World Wide Web Consortium. (2009). *Skos simple knowledge organization system reference*. Retrieved August 27, 2026, from <https://www.w3.org/TR/skos-reference/>
- World Wide Web Consortium. (2013). *Prov-o: The prov ontology*. Retrieved August 27, 2026, from <https://www.w3.org/TR/prov-o/>
- World Wide Web Consortium. (2014). *Rdf 1.1 concepts and abstract syntax*. Retrieved August 27, 2026, from <https://www.w3.org/TR/rdf11-concepts/>
- World Wide Web Consortium. (2020). *Json-ld 1.1*. Retrieved August 27, 2026, from <https://www.w3.org/TR/json-ld11/>
- Yumnam, H., Nath, S., & Sharma, I. (2026). Brewing traditions of northeast india, south assam: Exploring rice beer’s cultural significance and indigenous craftsmanship. *Biotechnology and Applied Biochemistry*, 73(3), 1501–1511. <https://doi.org/10.1002/bab.70113>