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Food Sovereignty Among the Halba Tribe of Bastar: An Anthropological Study of Traditional Food Preservation Practices

Dr. Anurag Mali [1], **Dr. Sunil Kumar Mehta** [2*]

[1] Alumnus, School of Studies in Anthropology, Pt. Ravishankar Shukla University, Raipur, Chhattisgarh, India

[2] Assistant Professor (Guest), Department of Anthropology, Govt. V.Y.T. PG Autonomous College, Durg, Chhattisgarh, India

Corresponding Author: * Dr. Sunil Kumar Mehta

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Abstract

Central Indian tribal communities face nutritional challenges due to rain-fed, single-cropping *Kharif* monoculture. In the Bastar Division, the indigenous Halba tribe of Kondagaon District experiences a seasonal resource crunch termed the 'Lean Period' during which households are socio-economically isolated from fresh perishables. This empirical study analyses the unwritten Indigenous Knowledge Systems utilised by the Halba community to achieve food sovereignty without modern refrigeration or synthetic stabilisers. Fieldwork was executed across four tribal settlements using purposive sampling to interview 120 key informants, paired with participant observation. The results establish that traditional preservation is a biochemical intervention aimed at reducing Water Activity, disrupting cellular breakdown, and degrading anti-nutritional factors. Botanically, practices range from dual thermal parboiling and solar cavitations of acrid tubers (Colocasia esculenta) into stable Khuila, to anaerobic, weevil-suffocating paddy storage inside straw rope Mair silos. In the ichthyo faunal domain, perishable biomass is transformed into durable Suksi variants through hypertonic dry salting of Mastacembelus armatus, vertical wood smoke phenolation of Esomus danricus, and chemical mortar compounding of Oecophylla smaragdina with wild tamarind to drop pH below 3.5. These zero-energy, zero-chemical methodologies offer climate-resilient blueprints for sustainable food packaging and off-grid security frameworks.

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1. INTRODUCTION

Food is not merely a biological necessity for survival; rather, from an anthropological perspective, it represents a profound socio-ecological manifestation of human adaptation and cultural resilience within an ecosystem. Indigenous Knowledge Systems (IKS), accumulated over centuries through experiential observation and passed down intergenerationally without written scripts, serve as primary survival toolkits for tribal societies globally (Roy et al., 2025). In the discourse of contemporary global crises, while modern societies confront structural vulnerabilities regarding Food Security and Food Sovereignty, indigenous communities residing in remote forest terrains continue to sustain their demographic pockets using localized resources and self-reliant preservation technologies (Rivera, 2025). The structural stability of these traditional food systems is deeply linked to the conservation of localized biodiversity, which offers an emergency safety net against severe climate shocks and systemic market fluctuations (Kennedy et al., 2022).

The southern region of Chhattisgarh, commonly known as the Bastar Division, is an ethnographically rich landscape inhabited by diverse indigenous communities including the Halba, Muria, Gond, Bhatra, and Dhurwa tribes. Among these, the Halba Tribe maintains a distinct socio-economic identity deeply anchored in agrarian practices. Etymologically, the name Halba is derived from the word 'Hal', meaning a ploughman, underscoring their historical transition into a prominent landowning agricultural community. Despite their strong agrarian affinity, the tribal farmers of Kondagaon and broader Bastar face severe structural bottlenecks. The virtual absence of modern canal networks or multi-crop irrigation infrastructures, combined with the continued practice of primitive, rain fed technologies, restricts their agricultural system to a single Kharif crop cycle (predominantly paddy). This mono cropping pattern creates a critical socio-economic challenge known as the 'Lean Period' or seasonal scarcity. During these transitional months (typically post harvest winter and peak summer), field operations stall, wage labour opportunities dry up, and poverty isolates households from external networks (Malta, 2019).

The lack of technological inputs and modern storage networks compounds this issue, making tribal settlements vulnerable to widespread seasonal nutrient gaps and underutilization of wild resources. Because severe economic vulnerability and geographic isolation prevent regular procurement of fresh perishables, the Halba tribe depends extensively on traditional food preservation to protect their nutritional baseline. This ethno preservation system relies entirely on low energy, eco friendly methods like smoking, solar dehydration, and natural insect repellents to manage microbes (Shukla et al., 2025). Documenting this unwritten knowledge is crucial, as modernization and shifting socio-economic pressures threaten to erase these time tested survival mechanisms.

From an anthropological standpoint, the food preservation techniques deployed by the Halba tribe of Kondagaon (Latitude: 19.59° N, Longitude: 81.67° E) represent a sophisticated, low-cost biochemical science. Rather than relying on modern energy-intensive appliances or synthetic chemical preservatives, they systematically alter the physical properties of organic foods. Dehydration techniques like solar drying, roasting in specialised earthenware, and parboiling drastically minimize Water Activity, effectively inhibiting microbial proliferation. The diverse inventory of preserved items spans across:

(i) **Vegetarian Resources:** Edible wild tubers (Kanda), bamboo shoots (Karil), and dehydrated leafy greens (Bhaji).
(ii) **Non-Vegetarian Resources:** Roasting small riverine fishes (Suksi), parboiling large fish in salted water, and wrapping meats tightly in biocidal Sarai (Shorea robusta) leaves.
(iii) **Ethno-Entomological Resources:** Processing structural proteins from specific insect colonies, such as Red Weaver Ants (Oecophylla smaragdina), into durable, acidic chutneys (Mata/Chapda Chatani) mixed with wild tamarind to suppress fungal growth.

This investigation focuses on documenting and evaluating these preservation practices among the Halba community in the Bade Rajpur block of Kondagaon district. At a time when climate shocks jeopardize conventional food supply chains, analysing this zero-chemical, zero-energy, and zero-waste tribal science provides key baseline data for designing resilient, localised food security frameworks globally.

2. MATERIAL AND METHODOLOGY

2.1 Geographical and Administrative Framework of the Study Area: The investigations for this research were systematically executed within the administrative boundaries of Kondagaon District, which covers a total territorial area of 5,078 square kilometres inside the central northern fringe of the Bastar Division in Chhattisgarh, India [Population Statistics, 2026]. Administratively, the micro level fieldwork was concentrated inside the Bade Rajpur Community Development (CD) Block, a tribal dominated pocket positioned roughly 15 kilometres from the sub-township of Vishrampuri (Baderajpur, Bade Rajpur, Kondagaon, Chhattisgarh, India). For a high-density evaluation of traditional knowledge, four specific tribal settlements characterised by high demographic saturation of the target community were selected: Koregaon, Bahigaon, Khajravand, Vyaparipara**.**

2.2 Agro-Climatic Parameters and Soil Profiling: The structural execution of indigenous preservation is highly dependent on local environmental variables. According to meteorological data modelling, the study site exhibits a sub humid tropical climate. The average annual rainfall ranges between 1,200 mm and 1,350 mm, with peak precipitation densely concentrated between June and September via the South West Monsoon. The mean annual thermal index shifts from a minimum of 11°C during winter to a maximum of 41.5°C during the pre-monsoon summer phase. Pedologically, the agricultural terrains of the selected villages are dominated by two native soil textures: *Kanhar* (Clayey Black Soil)- Characterized by high moisture retention capacity but highly prone to waterlogging during monsoons. *Matasi* (Yellowish Sandy Loam Soil) - Highly porous with poor moisture retention capacity, restricting non-irrigated winter cropping.

2.3 Socio-Demographic Matrix of the Target Population: Out of the total district population of 5,78,824 individuals, Scheduled Tribes (ST) constitute an overwhelming 405,414 individuals, making up approximately 70.04% of the absolute population. The average literacy rate across these interior zones stands at 57.31%. The rural pockets register lower functional literacy rates among older cohorts, which has structurally contributed to the preservation and uncompromised continuity of the oral Indigenous Knowledge Systems.

2.4 Research Design, Sampling, and Data Elicitation Tools: The structural framework of this study relies on a qualitative, descriptive, and exploratory Ethnographic Research Design.

2.4.1 Sampling Protocol: Because traditional preservation techniques are specialized skills requiring years of practice, a Purposive and Snowball Sampling Technique was employed to build a sample of 120 key informants across the four villages. The sample was structurally balanced between genders to capture distinct domains of knowledge: Female Informants (n=60) **-** Primarily interviewed for domestic preservation techniques, including thermal dehydration of leafy greens, wild tuber drying, processing of medicinal flowers, and insect-based compounding. Male Informants (n=60) **-** Primarily interviewed regarding resource collection architectures, deep forest foraging, field-level grain storage technologies (*Mair/Kothi*), and riverine fish preservation setups. **Age Stratification** - Priority was strictly assigned to senior community members aged 25 to 80 years, identified by local Gram Panchayats as core repositories of unwritten ancestral heritage.

2.4.2 Methods of Data Collection: Participant Observation - The researcher lived within the tribal pockets during key seasonal processing phases to record exact processing timelines, temperatures, and storage designs without altering natural behaviors. Semi-structured Interviews: Handled through an Ethnographic Interview Guide translated into Halbi and Chhattisgarhi dialects to prevent linguistic distortions. Questions focused on processing durations, local nomenclature, tools, and the shelf-life profiles of preserved items. Focus Group Discussions (FGDs): Eight separate FGDs (two per village, consisting of 8-10 participants each) were conducted at community centres to resolve discrepancies regarding processing timelines and botanical identification.

2.5 Taxonomic Verification and Biochemical Rationale: All botanical specimens, wild macro fungi, and ethno entomological subjects documented during the fieldwork were cross referenced and validated taxonomically using standard regional flora manuals. The preservation steps were analyzed from a biochemical standpoint, focusing on how traditional methods alter relative humidity and pH levels to stop microbial and enzymatic spoilage.

3. RESULTS AND DISCUSSION

3.1 Ethno-Botanical Resource Conservation and Bio-Chemical Dynamics: The preservation of vegetarian food items within the Halba homesteads of Kondagaon involves a systematic application of thermodynamic and chemical rules. Rather than being passive storage, these traditional practices are deliberate actions designed to lower Water Activity stop cellular breakdown, and degrade anti nutritional compounds present in wild forest plants - (i) Fresh Leafy Greens/ Tubers (ii) Thermal Treatment/ Parboiling (iii) Solar Cavitations (iv) Hermetic Earthen Cellarage (v) Biocidal Leaf Wrapping (vi) Moisture Drop (<12% Aw).

The preservation of subterranean corms, specifically *Colocasia esculenta* (Kochai Kanda) and *Amorphophallus paeoniifolius* (Suran/Jimikand), relies heavily on moisture control and physical protection. For *Colocasia esculenta*, the tribal practitioners use a twostep process: thermal parboiling followed by open solar desiccation. This process, locally termed *Khuila*, causes structural changes that denature vegetative enzymes and reduce calcium oxalate acridity crystals, which otherwise cause severe throat irritation. For the larger *Amorphophallus paeoniifolius*, the community uses a different approach. The whole tubers are kept intact and placed in dark, well ventilated, mud plastered storage spaces raised off the ground. By keeping the corms away from damp earth and maintaining a constant airflow, the outer skin dries out naturally. This creates a protective boundary that prevents fungal root rot (*Sclerotium rolfsii*) and allows the tubers to be stored for over thirty days without losing their nutritional starches. In contrast, preserving delicate forest resources like *Bombax ceiba* (Semal Kanda) and *Curcuma longa* (Haldi) requires shielding them from light and environmental humidity. *Bombax ceiba* roots are boiled to soften their starches, sliced, dried under the sun, and wrapped tightly in dense woven cotton fabrics. This fabric shield blocks moisture from re-entering the dry roots. For *Curcuma longa*, the community stores the harvest in completely dark, dry cellars. This dark environment is essential because it prevents daylight from breaking down curcumin, the primary active antiseptic compound. Similarly, the long-term conservation of the highly valued *Dendrocalamus strictus* (Karil/ Bamboo Shoots) requires removing its bitter components. The outer protective sheets are stripped away, and the tender inner cores are sliced thin and boiled multiple times. This boiling process leaches out toxic cyanogenic glycosides (taxiphyllin). The sliced shoots are then dried under intense sunlight until they are crisp, dropping their moisture content below twelve percent. **[Fig: 1, 2, 3.]**

Fig: 1 Bombax ceiba

Fig: 2 Hibiscus cannabinus

Fig: 3 Colocasia esculenta

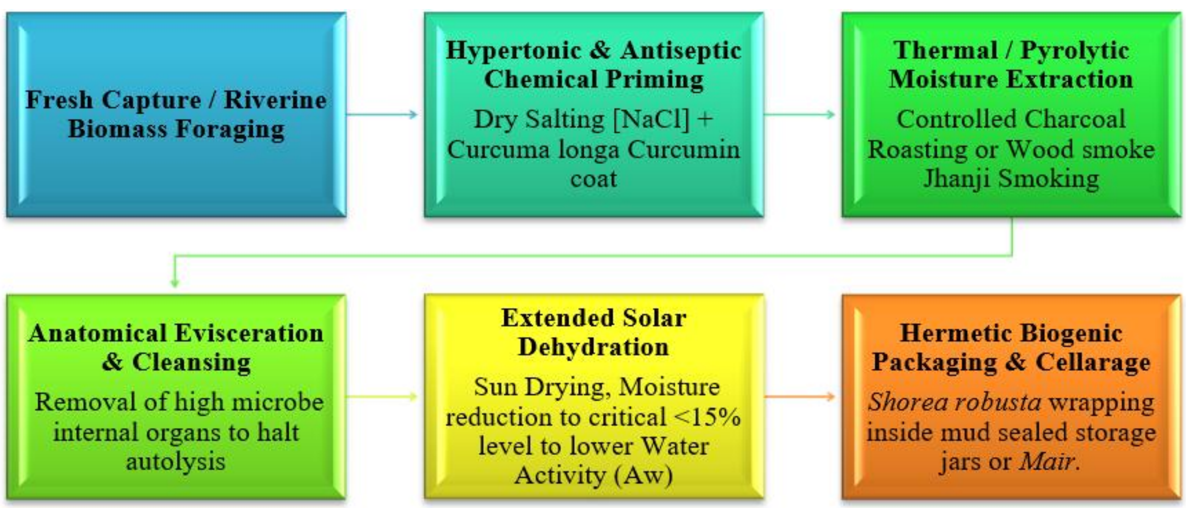
The preservation of seasonal leafy wild greens, such as *Hibiscus cannabinus* (Jhira Bhaji) and *Bauhinia purpurea* (Koilar Bhaji), highlights a deep understanding of natural chemistry. *Hibiscus cannabinus*, prized for its sour taste, is dry roasted on open unglazed clay plates before being transferred to porous bamboo baskets for final sun drying. The initial roasting step deactivates chlorophyll degrading enzymes, locking in its high ascorbic acid (Vitamin C) content. For *Bauhinia purpurea*, which is traditionally eaten with fermented rice starch (*Basi*), the leaves are roasted and dried over bamboo mats. This dry processing removes moisture while keeping the plant's structural proteins and dietary fibers intact, protecting them from mold during seasonal humidity shifts. The community also creates a unique dish called *Idhahar* using *Colocasia esculenta* leaves. Fresh leaves are coated with a thick paste of ground black gram (*Vigna mungo*) flour, rolled tightly, steamed, sliced, and sun dried. Fermenting and steaming the pulse flour releases organic acids that lower the food's pH. This acidic shift, combined with sun-drying, acts as a dual preservation method that yields a protein rich, storage stable product. The preservation of seasonal forest fruits like *Madhuca latifolia* (Mahua Flowers) and *Phyllanthus emblica* (Awla) demonstrates efficient large scale resource management. *Madhuca latifolia* flowers are dried on cleared ground under the sun until they turn from cream white to deep reddish brown. This solar drying concentrates their natural invert sugars, creating a highosmotic environment where bacteria cannot survive. The dried flowers are then packed tightly into deep clay bins (*Mair*), keeping them viable for over a year as an energy rich food source.

3.2 Ichthyo-faunal and Ethno-Entomological Bio Preservation Practices: In the micro climatic terrain of the Bade Rajpur block (Kondagaon), seasonal lotic and lentic water bodies dry up during the post-monsoon transition. To mitigate the subsequent drop in animal protein availability during the winter and summer squeeze, the Halba tribe has designed low-cost biochemical systems. These processes structurally transform perishable biomass into highly stable, dehydrated products collectively termed *Suksi* or *Jhanji*. The traditional processing of *Mastacembelus armatus* (Baambi) requires rubbing the live eel against coarse granitic stones to strip away its thick epidermal mucus before a deep longitudinal incision is made to eviscerate internal organs and prevent autolytic decay. The flesh is sliced into thick cross-sectional rings, rubbed with dry unrefined rock salt (Sodium Chloride), and laid over wood charcoal embers for initial thermal sealing before undergoing five to seven days of open solar desiccation on raised bamboo platforms, a hypertonic chemical shift that drops moisture content from seventy eight percent to a stable twelve percent and initiates bacterial plasmolysis to stop lipid oxidation for up to six months. Conversely, the processing of *Esomus danricus* (Kotri) leverages whole, un eviscerated micro fishes due to their low individual muscle mass which dries rapidly without spoiling. These small fishes are washed and spread across a suspended split bamboo mat structure called a *Jhanji*, which hangs permanently up to two meters directly above indoor firewood cook stoves (*Chulha*) to undergo weeks of low intensity wood smoke exposure that drops structural moisture down to eight percent while depositing natural phenols and guaiacol onto the skin to act as an antiseptic barrier against mold spores for eight to twelve months. For seasonal river crustaceans like *Macrobrachium lamerrei* (Jhinga), the preservation technique changes to a hydro thermal method where the whole unpeeled prawns are parboiled in a saline rich earthenware cauldron for fifteen minutes until their calcified chitinous shells turn orange pink, denaturing active endogenous proteases to halt meat softening before the biomass is spread across broad sun dried *Madhuca latifolia* leaves for five days of solar moisture extraction to reach a crisp ten percent moisture level that stays preserved for four months. Thick bodied riverine catfish such as *Clarias batrachus* (Mangur) demand deep diagonal muscle scoring across split open fillets to create exit channels for internal moisture, followed by packing the meat with layers of rock salt and drying them on dark. The preservation of *Channa punctatus* (Gadai) bypasses open sun drying by utilizing an unglazed terracotta griddle (*Tawa*) for oil free pan roasting to flash evaporate surface water and tighten outer tissues, after which the whole fish are layered inside porous clay jars alternated with dry paddy straw (*Paral*) and sealed with cloth, allowing the straw and porous clay to absorb rising internal humidity and prevent mold condensation for up to three months. Finally, the ethno entomological preservation of *Oecophylla smaragdina* (*'Mata'* Red Weaver Ant) relies on a chemical mortar technique where live adult ants, pupae, and nutrient dense larvae are crushed on a stone mortar with wild *Tamarindus indica* pulp, *Curcuma longa* powder, and rock salt into a paste that is wrapped tightly inside fresh *Shorea robusta* (Sarai) leaves. This combination mixes the ants' natural formic acid with the tamarind's tartaric acid to drop the compound's pH below 3.5, creating a high acid, tannin shielded environment that stops food borne bacteria and preserves the protein paste for three weeks without refrigeration. **[Fig: 4, 5, 6.]**



Fig: 4 Dendrobran chiata **Fig: 5** Heteropneustes fossilis **Fig: 6** Oecophylla smaragdina

3.3 Ethnographic Operational Flowchart of *'Suksi'* Processing: The procedural progression observed among Halba practitioners follow a strict processing logic designed to maximize preservation efficiency without external power or artificial chemicals: [**Flow Chart-1**]



3.4 Ecological and Nutritional Anthropology Insights: From an anthropological perspective, the processing of *Suksi* and ethno entomological resources like *Mata Chatani* goes far beyond simple food prep. It represents a vital ecological buffer strategy. In the nutritional economy of the Halba community, these preserved animal resources serve as critical supplies of essential amino acids (such as lysine and methionine), polyunsaturated fatty acids, and bio available iron during seasonal gaps. During the lean months, these micro nutrients are consumed alongside *Basi* (overnight fermented, cooled rice starch). This dietary pairing sustains working class energy levels and gut health, showing how traditional practices help maintain physical health and community resilience without relying on modern refrigeration networks.

4. ACADEMIC DISCOURSE OF INDIGENOUS FOOD PRESERVATION SYSTEMS

To contextualize the findings of this study, it is essential to evaluate the academic discourse surrounding indigenous food preservation systems within Central India. Anthropological investigations across the tribal pockets of the Central Indian landscape demonstrate that traditional food preservation is an existential response to severe agro climatic vulnerabilities rather than a mere culinary preference (Mishra et al., 2020). Studies focused on the Gond and Maria communities of the broader Bastar region indicate that these groups share a foundational reliance on thermal desiccation and solar drying to combat seasonal nutritional deficits (Sinha et al., 2016). However, the specific socio technical execution varies significantly based on tribal lineage and primary subsistence patterns. While the nomadic and hunting centric sections of the

Madia Gond rely extensively on primitive open air fire smoking for wild meats, the agrarian rooted Halba tribe demonstrates a more controlled integration of domestic technologies, such as the stratified *Jhanji* smoke mats positioned over permanent household hearths, which optimizes fuel wood efficiency and provides standard heat distribution for delicate micro fauna. Furthermore, ethno-botanical research highlights the unique ways different tribes manage toxic anti nutritional factors in wild forest foods. For example, while the Baiga tribe of the Maikal hills utilizes long underwater leaching in forest streams to remove toxins from wild yams, the Halba tribe of Kondagaon prefers combining thermal parboiling with solar cavitations to lower the acridity of *Colocasia esculenta*. This method successfully reduces harmful calcium oxalate crystals while keeping valuable starches intact (Singh & Misra, 2021). In terms of grain storage, research shows that the Halba tribe's *Mair* structures built from thick paddy straw ropes provide a superior anaerobic seal compared to the loose bamboo structures used by neighboring communities. By trapping carbon dioxide, the *Mair* design naturally suffocates storage pests without requiring chemical treatments. Additionally, the Halba tribe's unique approach to ethno entomology, seen in how they mix the formic acid of *Oecophylla smaragdina* with the tartaric acid of wild tamarind to drop the pH below 3.5, highlights a highly advanced understanding of natural biochemistry that sets their food preservation practices apart from other Central Indian tribes (Kumar & Rao, 2016).

5. CONCLUSION AND FUTURE SCOPE

This ethnographic and biochemical investigation confirms that the food preservation systems developed by the Halba tribe of Kondagaon are sophisticated, low-cost ecological strategies that effectively shield the community from seasonal food shortages during the 'Lean Period' By using natural resources such as local clays, sun exposure, plant derived tannins, and wood smoke the community successfully lowers water activity levels and balances pH thresholds to preserve perishable foods. These methods allow the tribe to maintain dietary health and absolute food sovereignty without needing artificial chemicals or modern, energy dependent cold storage. This zero waste, zero chemical, and zero energy tribal science serves as an excellent model for sustainable food management.

Looking ahead, as climate change increasingly threatens global food supply chains; these ancient techniques offer valuable lessons for modern food preservation. Future research should focus on analyzing the precise antimicrobial properties of biogenic packaging materials like *Shorea robusta* (Sarai) leaves and *Vitex negundo* (Sendhuar) leaves. Discovering the exact compounds that keep these foods fresh could help scientist's design biodegradable packaging that prevents mold and extends the shelf life of commercial foods naturally. Furthermore, scaling up these clean, low-cost tribal technologies could help remote, off grid farming communities protect their harvests, reducing food waste and strengthening local food security around the world.

6. POLICY AND IMPLICATIONS

Based on the findings, demographic constraints, and ethnographic field data gathered across the Bade Rajpur block, the following targeted interventions are proposed to safeguard, validate, and commercialize this indigenous knowledge system

(i) Establishment of Community Owned Traditional Dehydration Centers: The District Administration of Kondagaon, in coordination with the Ministry of Tribal Affairs, should establish localized processing centers equipped with modern solar tunnel dryers. These dryers can scale up the Halba tribe's natural zero energy sun drying logic. By standardizing clean dehydration parameters for seasonal wild leafy greens (*Bhaji*) and *Dendrocalamus strictus* (Karil), these centers can minimize post-harvest microbial rot, extend shelf stability, and create sustainable off-season livelihoods for local women's self-help groups (SHGs).

(ii) Biochemical Standardization and IP Protection of Ethnic Superfoods: There is an urgent need to protect the intellectual property rights of the Halba community's recipes, such as the *Idhahar* (fermented *Colocasia* leaf composite) and the *Mata Chatani* (Red Weaver Ant formulation). Public research institutions, such as the National Institute of Nutrition (NIN) and Central Food Technological Research Institute (CFTRI), should run comprehensive nutritional profiling and toxicological assays on these foods. Securing Geographical Indication (GI) tags or patent protections under the National Biodiversity Authority (NBA) will prevent commercial exploitation while establishing these products as highly nutritious ethnic super foods.

(iii) Integration of Sustainable Biogenic Packaging into the Green Economy: The unique tribal practice of using *Vitex negundo* (Sendhuar) leaves as a natural insect repellent and wrapping nutrient pastes tightly inside tannin-rich *Shorea robusta* (Sarai) envelopes should be researched for modern industrial packaging. Material scientists should extract the volatile terpenes and antimicrobial resins from these native plants to develop ecofriendly, biodegradable alternatives to single use plastics. This initiative would establish a circular bio economy, providing direct financial incentives to tribal forest collectors in Bastar.

(iv) Development of Decentralized Organic Grain Silos (Mair Prototypes): To decrease dependency on synthetic chemical fumigants like aluminum phosphide, agricultural bodies should evaluate and improve the structural mechanics of the traditional *Mair* (paddy straw rope storage). Engineering low cost, modernized anaerobic silos inspired by the *Mair* design can help smallholder farmers across Central India protect their grain naturally. This self contained, carbon dioxide buffering method naturally suffocates destructive storage pests, preserving grain quality cleanly and economically.

(v) Inclusion of Tribal Ethno-Nutrition in Local Health and Educational Frameworks: To counter generational knowledge loss caused by low functional literacy among tribal youth and the shift toward processed commercial foods, this unwritten ethno biological heritage must be preserved. State educational boards should include documented chapters on local ethno botany, tribal conservation, and indigenous nutrition within school curriculums in Bastar. Additionally, community health departments can integrate iron rich traditional preparations, like preserved fish *Suksi* and ascorbic acid dense dried greens, into local Anganwadi nutrition programs to fight seasonal anemia and malnutrition natively.

7. LIMITATIONS OF THE STUDY

While this study provides valuable ethnographic insights into the traditional food preservation systems of the Halba tribe, several inherent limitations must be acknowledged:

- **Geographic and Ethnic Constraints:** The empirical fieldwork was strictly restricted to four specific settlements within the Bade Rajpur block of Kondagaon District, focusing exclusively on the Halba tribe. Consequently, the findings cannot be broadly generalized to represent the entire Bastar Division or other diverse ethnic groups (such as the Muria, Madia, or Gond tribes) who may utilize different socio-ecological preservation mechanisms.
- **Methodological Reliance on Memory Recall:** The data gathering relied heavily on ethnographic interviews, memory recall, and oral history from key community elders. This subjects the timelines for product shelf life and historical preservation workflows to potential recall bias or subjective variations among informants.
- **Lack of Quantitative Laboratory Validation:** While the paper establishes the empirical, biochemical, and thermodynamic rationale behind methods like solar cavitation, pyrolytic smoking, and acid compounding, the study lacks direct laboratory verification. No quantitative testing (e.g., measuring exact water activity, precise pH value shifts, microbial load plating, or nutritional loss tracking) was performed on the preserved samples.
- **Sample Size Constraints:** A sample size of 120 key informants, while sufficient for a localized ethnographic qualitative matrix, restricts the ability to run broader multi variable statistical models or cross regional comparative analyses.
- **Temporal and Seasonal Constraints:** The fieldwork captured specific seasons of resource scarcity but did not track long-term variations in preservation efficacy across multiple consecutive years under fluctuating climate patterns.

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About the Author

Dr. Anurag Mali has earned a Doctor of Philosophy (Ph.D.) in Anthropology with a specialization in Social Anthropology. He has also qualified the prestigious UGC-NET examination during Post graduation in Anthropology, demonstrating his academic excellence and research competence. His research interests focus on society, culture, social change, tribal communities, and issues related to social justice. During the previous year, he served as Centre In charge-cum-Counsellor under the 'ODIC' Project of the Ministry of Social Justice and Empowerment, Government of India, where he successfully managed administrative responsibilities, counselling services, community outreach, and rehabilitation initiatives. Dr. Mali is deeply committed to teaching, research, and community engagement. His visions is to utilize anthropological knowledge for the empowerment of marginalized communities, contribute to evidence based policymaking, and inspires students through quality education and meaningful research.

Dr. Sunil Kumar Mehta is an Assistant Professor (Guest) in Anthropology at Govt. V.Y.T. PG Autonomous College, Durg, and a UGC NET qualifier. With expertise in human biology, molecular/population genetics, and anthropometry, he supervises B.Sc. and M.Sc. research. His fieldwork-focused research targets farmers/tribal/rural development, women and child studies, and health and nutritional status.