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INDIGENOUS KNOWLEDGE SYSTEMS (IKS) AND MATERIAL CULTURE OF CAMEL MEAT PRESERVATION: IMPLICATIONS FOR FOOD SECURITY IN BERHALE DISTRICT, ETHIOPIA

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ABSTRACT

This research documents the indigenous knowledge and material culture used to preserve camel meat in Berhale district. In the lowlands of Ethiopia's Danakil Depression, the territory where extreme thermal stress makes modern refrigeration nonexistent, the dromedary camel (*Camelus dromedarius*) remains the primary safeguard against food insecurity for Afar pastoralist communities. Data were gathered from 90 households through multi-stage sampling, utilising structured interviews and focus group sessions to track how raw meat is converted into *Muqmad*, a long term protein reserve. The study found that Afar elders effectively utilise hurdle technology through a layered defense: solar drying, antimicrobial smoking and sealing the meat in rendered camel tallow. These cultural zero energy techniques keep the meat edible for up to a year, even when outside temperatures exceed 45°C. A critical component of this system is the *Xeedho*, a specialised wooden vessel that acts as an airtight storage unit to block oxygen and stop the fat from turning rancid. While these methods are essential for surviving seasonal hunger, the local industry is held back by informal trade routes and inconsistent quality measures. I argue for a scientific hybridity approach merging Afar expertise with modern food safety standards like Hazard Analysis and Critical Control Point (HACCP). By standardising these local methods, *Muqmad* can be transformed from a local survival food into a high value, clean label export, protecting both Afar heritage and regional food supplies in an increasingly volatile climate.

Key words: Camel meat preservation, climate resilience, danakil depression, hurdle technology, *Muqmad*, *Xeedho*

In Ethiopia, camel husbandry is a practice woven into the socio-economic and cultural fabric of the Somali and Afar regions. In these arid lowlands, the dromedary camel (*Camelus dromedarius*) is far more than a livestock asset; it is a fundamental survival mechanism. During protracted droughts, when cattle and small ruminants often face catastrophic losses, camels provide a resilient supply of milk and meat, sustaining both nomadic mobility and nutritional security (Yosef *et al,* 2013; Megersa, 2024). This adaptive capacity is supported by significant genomic diversity, allowing indigenous populations to remain productive under the extreme thermal stress of the Horn of Africa (Yakubu *et al,* 2022; Robert, 2018).

In the Berhale district, situated on the periphery of the Danakil Depression, the Afar people operate in one of the hottest environments on Earth. Here, the limited access of electrical infrastructure and modern refrigeration has forced a sophisticated evolution of indigenous technical resilience. Afar food preservation is not merely a survival tactic but a refined system of ethno-microbiology. For instance, medicinal flora are used to smoke wooden vessels to inhibit pathogens (Karssa *et al,* 2024) and botanical extracts serve as natural sanitizers to mitigate lipid oxidation (Seifu, 2007). Furthermore, specialised dehydration and deep frying processes allow meat to remain shelf stable for up to a year, providing a vital caloric reserve against climatic uncertainty (Dabasso *et al,* 2018).

The necessity for these methods is driven by the unique rhythms of pastoral life. Camel slaughter is rarely routine; it is typically reserved for major festivals, severe droughts, or emergency culling. This results in a sudden, substantial surplus of meat that must be stabilised immediately to prevent waste. Despite the camel's vital role in navigating Ethiopia's climatic shifts (Teku, 2025), the sector remains systemically underdeveloped. Regional agricultural research has historically exhibited a bovine bias, prioritising cattle while overlooking the adaptation strategies essential to the lowlands (Egeru *et al,* 2022).

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Moreover, camel meat presents specific biochemical challenges. Its high moisture content and elevated pH make it more susceptible to microbial spoilage than other red meats (Rezaei *et al,* 2026). While modern technologies like vacuum packaging offer potential solutions, there is a critical need to bridge the gap between industrial safety standards and traditional mastery.

This study addresses this gap by documenting the tools and indigenous techniques of the Afar in Berhale. By integrating field surveys and systematic photography with modern food science, this research seeks to document traditional preservation methods and their cultural equipment. Ultimately, empowering these eco-friendly, consumer accepted strategies can strengthen the camel value chain and secure the livelihoods of pastoralist communities in an increasingly volatile climate.

Materials and Methods

Study Area and Environmental Context

The fieldwork was centered in the Berhale district, a key pastoral corridor in Zone 2 of Ethiopia's Afar Regional State. Indeed, recent census data (Sintayehu *et al,* 2024) shows that camel density in Berhale far outstrips that of cattle or small ruminants. This makes the district a prime location for studying how indigenous knowledge maintains meat stability in temperatures that would otherwise cause rapid spoilage.

Sampling and Research Design

The research used a multi-stage sampling approach to capture data from both pastoral and agro-pastoral households. First, five administrative units (kebeles) were purposively selected based on three factors: high camel populations, a continued reliance on traditional meat processing and accessibility. From these kebeles, 90 households were chosen through stratified random selection. To verify our findings, we triangulated data using three primary methods: Structured Surveys: To gather quantitative data on household preservation habits. Focus Group Discussions (FGDs): Sessions with community elders to record the ancestral logic and oral history behind preservation techniques. Field Observations: Direct verification of the processing steps, specifically the techniques used during dehydration and deep frying.

Documentation of Material Culture

To record the Afar people's traditional preservation equipment, the study followed a specialised ethnographic protocol. We catalogued indigenous tools, including cutting implements and storage vessels. We recorded their local names, the specific woods or fibers used in their construction and their specific roles in the preservation cycle. Every stage of the process and each piece of equipment was documented with high resolution photography. This visual archive serves to validate household reports and creates a permanent record of Afar meat processing heritage.

Data Management

Quantitative data were analysed using SPSS to produce descriptive statistics, such as frequencies and percentages of specific habits. Qualitative insights, including indigenous proverbs and survival logic shared by the elders, were analysed through thematic coding to better understand the cultural values supporting these traditional systems.

Results and Discussion

Livestock Holding Patterns and Diversity

Empirical evidence from Berhale indicates that 70% of pastoral households strategically maintain mixed species herds, predominantly integrating camels with goats (Table 1). This management paradigm facilitates stratified foraging, allowing livestock to exploit both browse and herbaceous biomass effectively. Such taxonomic diversification functions as a biological insurance policy, safeguarding communal livelihoods against species specific pathological outbreaks or abrupt thermal fluctuations (Egeru *et al,* 2022). Notably, the traditional reliance on massive, single species assemblages has diminished, with only 7.8% of modern herders maintaining camel exclusive

Table 1. Distribution of livestock species among surveyed households in Berhale district (n = 90).

Herd Composition	Pastoral (n=76)	Agro-pastoral (n=14)	Combined (n=90)
Camels and Goats	75.0%	46.2%	70.0%
Camels, Goats and Donkeys	7.9%	15.4%	8.9%
Camels only	7.9%	7.7%	7.8%
Goats only	3.9%	14.3%	5.6%
Camels, Goats and Sheep	2.6%	7.7%	3.3%
Camels, Goats, Donkeys and Sheep	1.3%	7.7%	2.2%
Full Mixed Herd (all species)	1.3%	7.7%	2.2%

holdings. This transition signifies a calculated shift toward environmental flexibility, as Afar households prioritise resilience over herd size to navigate the increasingly volatile climate of the Depression (Demissie *et al,* 2024).

Livestock species distribution and tropical livestock units (TLU)

The quantitative assessment in Berhale District demonstrates a definitive dominance of camels and goats within the household livestock portfolio (Table 2). Camels accounted for the highest mean Tropical Livestock Unit (TLU) at 4.6 per household, followed by goats at 2.2 TLU. In contrast, the contribution of cattle, sheep and donkeys to the total TLU was remarkably low; specifically, cattle were owned by only two surveyed households, with a mean TLU of 1.05. This distribution is fundamentally driven by the extreme environmental stressors characteristic of the Northern Afar lowlands. The hyper arid climate and proximity to the Danakil Depression impose severe physiological constraints on cattle and sheep, which exhibit lower thermo-tolerance and higher water requirements than the dromedary (Sintayehu *et al,* 2024). Extensive regional modeling confirms that a strategic shift from cattle to camel and goat farming in north sub Saharan Africa's dry lands can sustain milk and meat production with significantly lower resource inputs and lower environmental emissions (Rahimi *et al,* 2022).

Consequently, the livestock composition in Berhale represents a localised optimisation of this survival model. While other regions may still support bovine centric systems, the producers in this study area have de-stocked sensitive species in favor of the dromedary, which maintains higher productivity and lower mortality rates under the current trajectory of climate uncertainty (Teku, 2025). This transition ensures a steady supply of animal source proteins even during the prolonged dry spells characteristic of the Afar depression.

Table 2. Distribution and Tropical Livestock Units (TLU) of species owned per surveyed household in Berhale District.

Livestock Species	N	Minimum	Maximum	Mean ± S.E	Mean TLU	TLU Range
Camels	85	1.0	29.0	4.6 ±0.43	4.60	1.0 – 29.0
Goats	83	2.0	100.0	22.0 ±1.89	2.20	0.2 – 10.0
Donkeys	12	1.0	4.0	1.7 ±0.28	0.85	0.5 – 2.0
Sheep	6	1.0	5.0	3.2 ±0.65	0.32	0.1 – 0.5
Cows	2	1.0	2.0	1.5 ±0.50	1.05	0.7 – 1.4

Note: N = Number of households owning the species. TLU conversion factors used: Camel = 1.0, Cattle = 0.7, Donkey = 0.5, Goat/Sheep = 0.1. The total TLU is the sum of the means for all species recorded in the study area.

Comprehensive Camel Meat Production and Step by Step Indigenous Preservation of Camel Meat in Berhale

In the Berhale district, the transformation of raw camel meat into a stable, yearlong food reserve follows a precise sequence of indigenous engineering steps. This process successfully manages the extreme 45°C ambient temperatures without any reliance on a cold chain.

Phase 1: Strategic Selection and Cultural Slaughter

Research in the Berhale district indicates a highly structured approach to camel slaughter, governed by both demographic and cultural priorities. The vast majority of households (83.3%) specifically select male camels for slaughter, while a smaller cohort (16.7%) utilises both adult males and females. A definitive age specific preference exists, with 91.1% of households slaughtering camels between 5 and 7 years of age. Only 8.9% of respondents reported slaughtering older camels, typically as a culling strategy when animals cease to be functional for transport or reproductive purposes. This specific window ensures the meat is mature enough for high protein yield while keeping the texture suitable for dehydration. Reproductive females are strictly excluded to maintain herd growth. These selection patterns align with established observations in the Horn of Africa, where adult males consistently represent the primary slaughtered stock to preserve the reproductive potential of the herd (Sintayehu *et al,* 2024; Kibebew *et al,* 2021).

The reluctance to slaughter young males is rooted in indigenous reproductive wisdom; local belief suggests that early slaughter of a male calf may negatively influence the dam's future conception of male offspring. Furthermore, female camels are strictly reserved for breeding and are only slaughtered upon confirmation of infertility. Due to the absence of formal abattoirs and the logistical challenge of processing large carcasses, 100% of slaughtering in Berhale occurs in open forest or stony areas. Traditional equipment, including the *Gile* (a specialised Afar cultural knife), axes and ropes, remain the primary tools for processing. Local producers estimate the edible meat yield of a single adult camel to be equivalent to that of 12 goats, underscoring the species' substantial role as a high volume protein source in the Afar food system.

Slaughter occurs in open, elevated stony areas. This choice of location is deliberate; the stones provide a clean surface and the elevation ensures high velocity airflow to begin cooling the carcass immediately. Using the *Gile* (Afar cultural knife), the carcass is segmented. Lean muscle is separated from the hump fat (tallow), which will later serve as the primary preservative medium.

Phase 2: Precision Slicing, Indigenous Rack Drying and Medicinal Smoking

The lean meat is carved into uniform, thin strips (Fig 1). This increases the surface-area-to-volume ratio, facilitating rapid moisture loss. Strips are draped over wooden racks or ropes. Intense solar radiation and dry winds reduce the water activity to a level where proteolytic bacteria cannot thrive. While drying, producers often ignite specific medicinal flora beneath the racks. The smoke deposits phenolic compounds on the meat, acting as a natural chemical shield against pathogens and insects (Karssa *et al,* 2024).

Fig 1. Indigenous meat preservation in Berhale Woreda, showing the lean meat is carved into uniform, thin strips for sun drying to achieve moisture reduction and long term protein stability.

Phase 3: Dicing, Tallow Rendering and Deep Frying

The brittle, sun dried strips are cut into small, uniform cubes. The saved hump fat is placed in a large pot and heated until it melts into a clear, boiling liquid. The meat cubes are submerged in the boiling fat. This step serves as a thermal hurdle, killing any surviving surface microbes and evaporating any remaining internal moisture (Fig 2).

Fig 2. The brittle, sun dried strips are cut into small, uniform cubes. Dehydrated, fire treated and cubed camel meat (*Muqmad*) prepared for long term storage.

Phase 4: Bio-Preservation and Sealing

During the final minutes of frying, a mixture of dates, cardamom and garlic is added. These are not merely flavorings; they are potent natural antioxidants that prevent the fat from turning rancid in the desert heat (Djenane *et al,* 2020). The meat is moved into traditional storage containers and completely covered with the hot rendered fat. As the fat cools and solidifies, it creates a physical airtight seal. This lipid barrier prevents oxidation and blocks secondary rehydration from the atmosphere. In the absence of cold chain infrastructure and under the 45°C ambient heat of Berhale, 86.7% of households utilise a meat preservation strategy centered on integrated sun drying and light fire smoking (Fig 3 and 4). This indigenous engineering model leverages natural high velocity airflow and intense solar radiation to rapidly reduce water activity in the meat, thereby inhibiting the proliferation of proteolytic and pathogenic bacteria. This method is scientifically recognized as one of the most effective low input stabilisation models for high protein assets in hyper arid landscapes (Sintayehu *et al,* 2024).

The primary output of this traditional engineering is *Muqmad*, produced through a rigorous three stage stabilisation process designed to achieve multi month shelf stability: **Dehydration Phase:** Lean muscle strips are hung on indigenous wooden racks for primary moisture reduction. **Thermal Stabilisation:** The dehydrated meat is cubed and deep fried in rendered camel tallow (hump fat). This

Fig 3. The leather wrapped exterior of the *Xeedho*, demonstrating the indigenous sealing mechanism that ensures an airtight environment for *Muqmad*. This specialised hardware is designed to withstand high impact transport and extreme thermal fluctuations, effectively acting as a portable, low entropy barrier against microbial contamination and environmental moisture.

Fig 4. The storage and transport of *Muqmad* rely on the *Xeedho*, a specialised, hand carved wooden bowl. The image displays the results of the final shelf stable product capable of resisting microbial spoilage for up to 12 months in the Afar climate.

step eliminates residual moisture and encapsulates the protein in a lipid barrier, preventing secondary rehydration and oxidation. **Bio-preservation Phase:** A final hurdle technology approach is applied by seasoning the meat with dates, cardamom and garlic. These spices are not merely flavorants; they function as natural antioxidants and antimicrobial agents that further suppress lipid oxidation and microbial growth (Dabasso *et al,* 2018; Djenane *et al,* 2020).

Data analysis reveals that 70.5% of households in Berhale achieve a shelf life of 6 to 8 months for *Muqmad*, with some respondents reporting product stability for up to a full year without refrigeration (Table 3). Consequently, this preserved meat serves as a critical food security buffer during protracted dry seasons and a vital nutrient source for women during postpartum recovery, demonstrating the profound socio-economic utility of Afar indigenous knowledge.

Table 3. Traditional meat processing (*Muqmad*) and storage in Berhale district.

Feature	Description / Finding
Indigenous Name	*Muqmad* (also known as *Oodkac*)
Technical Steps	Sun-drying > Slicing > Deep-frying in tallow > Spicing
Natural Preservatives	Cardamom, garlic, camel tallow (ghee) and *Temir* (dates)
Household Adoption	86.7% of surveyed households
Stability / Shelf Life	6 to 8 months (up to 12 months in optimal conditions)
Cultural Hardware	*Xeedho* (Decorated, leather wrapped wooden bowl)
Dietary Role	Survival food
Relative Yield	1 camel estimated at 12 goats in meat volume

Indigenous Knowledge and Resilience Features

The preservation systems in the study area are not merely traditional practices; they represent a sophisticated application of Climate Intelligence and Resource Engineering. Below is a breakdown of the core resilience features that define these indigenous systems.

Step 1: Application of the Multi Hurdle Strategy

The pastoralists in the study area effectively apply what modern food science calls Hurdle Technology. By layering multiple preservation barriers, they ensure that if one hurdle fails, others are in place to prevent microbial growth. Heat (Boiling/ Frying): The first hurdle, which reduces the initial microbial load through thermal sterilisation. **Salt:** Acts as a solute to increase osmotic pressure, drawing moisture out of microbial cells. Drying: Lowers the water activity, making the environment too dry for bacteria to reproduce. Fat Encapsulation: The final hurdle, which creates a physical barrier against oxygen and moisture reentry.

Step 2: Resource Optimisation and Circularity

The system is designed to be entirely self-sufficient, requiring zero external inputs or synthetic chemicals. Utilisation of Hump Fat: Instead of discarding the hump, its high quality tallow is used as the primary preservative and energy source for the meat. No External Preservatives: The process relies exclusively on local salt and botanical extracts (garlic, ginger, or medicinal smoke). Zero Waste: Every component of the carcass is utilised, ensuring high resource efficiency in a resource scarce environment.

Step 3: Synchronisation with Climate Intelligence

Indigenous techniques are strategically timed to align with environmental cycles, ensuring a high success rate. Seasonal Timing: Preservation is synchronised with the dry seasons when humidity is lowest and dehydration is most rapid. Solar Harnessing: Techniques leverage in Berhale district high solar radiation as a free, consistent energy source for moisture removal. Environmental Compatibility: Because the methods are built around the local climate (high heat and low humidity), they are more reliable than modern technologies like refrigeration, which often fail due to power instability.

Step 4: Engineering for Mobility Compatibility

For nomadic and transhumant communities, food must be as mobile as the herd. The preservation process transforms heavy, perishable raw meat into a transportable asset. Light weighting: By removing up to 70-80% of the meat's water content, the resulting product is significantly lighter and easier to carry. Non-Perishability: Products like *Muqmad* do not require specialised storage, allowing them to be packed in traditional leather bags or containers during long migrations. High Energy Density: The combination of protein and fat provides a concentrated nutrient source for herders traveling across vast distances.

Storage Culture and Symbolic Materiality

The storage and transport of *Muqmad* rely on the *Xeedho*, a specialised, hand carved wooden bowl (Fig 4). Observations in Berhale suggest that the *Xeedho* is not merely a functional container but a sophisticated cultural storage system. When the fried meat is submerged in dates within these airtight, leather wrapped vessels (Fig 5), it is shielded from oxidative rancidity and microbial contamination. Beyond its practical utility, the *Xeedho* frequently decorated with cowrie shells serves as a primary cultural signifier of household wealth and social status. This indigenous material culture enables the Afar of Berhale to maintain a stable, high protein food supply during long distance migrations. Such a resilient food engineering system represents a generational adaptation to the ecological pressures of the Danakil depression.

Nutritional and Food Security Role

In the Berhale district, preserved camel meat is not merely a food item; it is a vital nutritional insurance policy. Its role in local resilience is defined by key pillars: **Drought Proof Protein Reserves:**

Fig 5. A specialised, hand carved wooden bowl known as the *Xeedho*, used for the long term storage and transport of *Muqmad*. The image illustrates the leather wrapped, airtight construction and cultural ornamentation, which together function as a low entropy storage system to protect the preserved meat from oxidative rancidity during migration.

When environmental shocks deplete bovine populations, *Muqmad* provides a high protein, energy dense reserve that remains stable without refrigeration. **Year Round Availability:** Indigenous preservation transforms a seasonal surplus into a consistent, year round nutrient source, bridging the hunger gap during the long dry seasons. **Medicinal Perceptions:** Local Afar communities value camel meat for its perceived medicinal properties. Lean Composition: Its high protein-to-fat ratio and unique amino acid profile make it a preferred dietary staple.

Constraints and Risks

While the indigenous systems are remarkably resilient, they face specific challenges that limit their potential for broader market integration: Processing Hygiene: 100% of slaughtering occurs in open air environments, which, despite the use of stony areas for cleanliness, exposes meat to environmental contaminants. Contamination Risks: Without controlled environments, meat is susceptible to dust, opportunistic insects and secondary microbial blooming if drying is interrupted by sudden humidity. Lack of Standardisation: Traditional methods rely on sensory cues (sight and touch) rather than standardised metrics, leading to inconsistent moisture content and varying shelf life between batches. Safety Awareness: There is a limited formal understanding of modern food safety protocols during the handling and dicing phases.

Scope for Scientific Integration

The future of the Ethiopian camel meat sector lies in the hybridity of traditional mastery and modern food technology. Integrating scientific standards can transform *Muqmad* from a local staple into a high value export product. Improved Dehydration: Implementing Solar Dryers can protect meat from dust and insects while maintaining the zero energy profile of the traditional process. Advanced Packaging: Utilising Vacuum Packaging for *Muqmad* could extend its shelf life even further and make it suitable for urban retail and international markets. Microbial Standardisation: Conducting systematic studies on the ethno-microbiology of Afar spices (garlic, dates and medicinal smoke) to identify and concentrate the most effective natural preservatives. Quality Frameworks: Applying HACCP (Hazard Analysis and Critical Control Points) to the indigenous workflow to ensure consistent safety and quality, facilitating certification for the global clean label market.

Conclusion

The indigenous knowledge systems of the Berhale district represent a sophisticated, self-sustaining bio-preservation technology perfectly calibrated to the extreme thermal conditions of the Danakil Depression. This research demonstrates that Afar pastoralists have engineered effective strategies to mitigate meat spoilage in the total absence of modern cold chain infrastructure.

The production of *Muqmad* is, in essence, a master class in Hurdle Technology. By layering multiple microbial barriers, thermal sterilisation, solar dehydration, osmotic pressure (salt) and lipid encapsulation, the community achieves a zero-energy stabilisation model. This allows high-value protein assets to remain stable for up to 12 months in ambient temperatures exceeding 45°C.

By transforming seasonal livestock surpluses into long term nutritional reserves, the preservation process acts as a vital insurance policy against the cyclical droughts characteristic of the Ethiopian lowlands. The transition toward mixed species herds (camels and goats) signifies an adaptive shift toward environmental flexibility, prioritising survival and resource efficiency over raw herd size. The *Xeedho* is not merely a vessel; it is a specialised engineering tool designed to maintain a low entropy environment. Its ghee-sealed, airtight construction reflects a profound inherited understanding of anaerobic food chemistry.

Despite its success, the sector faces constraints from open air processing risks and a lack of metric standardisation. The path forward lies in Scientific Hybridity: integrating time-tested indigenous mastery with modern advancements. By strategically introducing solar dryers, vacuum packaging and HACCP based quality frameworks, the Afar community can bridge the gap between traditional survival and global safety standards. Such an evolution will not only bolster local food security but also position *Muqmad* as a premium, clean label export product, safeguarding the resilient cultural heritage of the Afar people against the shifting pressures of the twenty first century.

Declarations

Availability of Data and Materials

To maintain academic transparency and accountability, the primary datasets generated and analysed during this study are available from the corresponding author upon reasonable request.

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Ethics Approval and Consent

This study was executed following the established ethical protocols for agricultural and social research. All participating pastoralist households provided informed verbal consent after being briefed on the study's purpose. Participants were assured of complete anonymity and the confidentiality of their responses prior to the data collection process.

Manuscript Status and Originality

The author certifies that this manuscript is an original work that has not been published elsewhere, in part or in full and is not currently under consideration by any other journal.

Conflict of Interest

The author declares no financial, professional, or personal affiliations that could represent a potential conflict of interest. No external influence or funding impacted the objectivity of the presented findings.

Author's Contribution

The author was solely responsible for the end-to-end execution of the project, including the initial conceptualisation, study design and field data acquisition. Additionally, the author performed all statistical analyses, interpreted the results and was responsible for the drafting, critical revision and final approval of the manuscript.

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