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Processing, preservation, and value addition of indigenous food crops in West Africa

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This review paper examines the processing and preservation methods of indigenous food crops in West Africa with a focus on their importance for nutrition security as part of the strategies to mitigate the adverse effects of climate change. Indigenous crops are nutritious, climate resilient and important in the diets of local communities. However, they tend to be underutilized when addressing national and regional food security needs. This paper explores the use of indigenous traditional food processing and preservation methods as well as the use of modern and innovative technologies for the reduction of postharvest losses, maintenance of nutritional quality, value addition and increased shelf-life, to ensure the year-round availability and affordability of these food crops. The paper also demonstrates how the integration of indigenous traditional methodologies with more modern processing techniques can increase the utilization of indigenous food crops with improved livelihoods for smallholder farmers and additional benefits for national and regional food security. Findings show that traditional methods remain vital but are faced with hygiene and labor challenges, while modern technologies improve efficiency but are costly. Integrated approaches enhance food safety, nutrient retention, and market access, empowering women and smallholder farmers. The paper recommends gender-responsive policies, decentralized processing hubs, and participatory innovation to scale integrated methods for resilient food systems.

KEYWORDS

indigenous food crops, processing, preservation, shelf-life, climate change

Highlights

- Document and optimize community techniques through participatory research and local training hubs.
- Scale affordable, gender-sensitive innovations (solar dryers, starter cultures, mechanization) via cooperative purchasing schemes and tech-transfer partnerships.
- Embed indigenous-crop processing in national policies, allocate funding for decentralized processing hubs, and roll out gender-responsive finance, market linkages and extension services.

1 Introduction

West Africa is home to a rich diversity of indigenous African food crops that have sustained communities for generations. These crops, including pearl millet (*Pennisetum glaucum*), sorghum (*Sorghum bicolor*), cowpea (*Vigna unguiculata*), fonio (*Digitaria* spp.), yam (*Dioscorea* spp.), Turkey berry (*Solanum torvum*) and a wide variety of African leafy vegetables, are uniquely adapted to the region's agroecological conditions, and are resilient to drought, poor soils, and erratic rainfall (Rouamba et al., 2023; Satyavathi et al., 2021). In addition to their agronomic advantages, these crops are deeply embedded in local food cultures, ceremonies, and livelihoods, particularly among smallholder farmers and women-led enterprises (Akinola et al., 2020; Misereor, 2022). Despite their nutritional richness and climate resilience, indigenous crops remain underutilized in national and regional food security strategies. One of the key barriers to their broader adoption is the limited development and dissemination of effective postharvest processing and preservation methods (Onomu, 2023). Traditional techniques such as fermentation, sun-drying, roasting, and soaking, have long been used to extend shelf life, enhance flavor, and reduce antinutritional factors. However, these methods are often labor-intensive, variable in quality, and vulnerable to contamination (Aworh, 2008; Asogwa et al., 2017). Indigenous African food crops, as used in this paper, are defined as plant species domesticated or long adapted within West Africa, having historical, cultural, and ecological significance in local diets and farming systems (Akinola et al., 2020; Misereor, 2022). These can be classified into five categories: (1) cereals and grains, (2) tubers and root crops, (3) leafy vegetables, (4) fruit trees, and lastly legumes and pulses. The classification referred to reflects both their botanical characteristics and their roles in traditional diets and agricultural systems. Their selection for this review reflects both their nutritional importance and their role in traditional West African food systems. To understand how these crops can be better harnessed, it is essential to clarify the core concepts that underpin their sustainable utilization.

Processing refers to the transformation of raw agricultural produce into forms that are safer, more palatable, and easier to transport, store, or market. Preservation encompasses traditional and modern techniques that maintain the safety, nutritional quality, and shelf-life of food, protecting it from spoilage and loss (Aworh, 2008; Asogwa et al., 2017). Value addition goes a step further by enhancing the economic and nutritional worth of these crops through innovative uses, product diversification, and fortification, thereby creating new market opportunities and improving household incomes (OECD E, 2016; Erelu et al., 2023). Together, these concepts form a crucial triad for strengthening the role of indigenous crops in building resilient food systems. In recent years, there has been growing interest in integrating modern and innovative technologies, such as solar drying, vacuum packaging, and improved fermentation starters, with indigenous knowledge systems. These hybrid approaches offer promising pathways to reduce postharvest losses, maintain nutritional quality, and add value to indigenous crops, thereby improving their year-round availability and market competitiveness (Erelu et al., 2023; Rahman et al., 2024).

This review examines the spectrum of traditional and modern processing and preservation methods applied to indigenous food crops in West Africa. It explores their implications for nutrition security, climate adaptation, and smallholder livelihoods. By

highlighting opportunities for technological integration and policy support, the paper aims to inform strategies that can elevate the role of indigenous crops in building resilient, inclusive, and sustainable food systems across the region.

2 Methodology

This study utilized a narrative, non-systematic review approach to explore traditional and modern processing techniques for indigenous crops in West Africa. Rather than following a rigid protocol, literature was selectively gathered from academic databases, institutional repositories, and practitioner platforms based on contextual relevance and thematic richness. The review incorporated peer-reviewed articles, technical reports, policy documents, and case studies published between 2000 and 2025. Through flexible thematic synthesis, the analysis focused on key areas such as food processing practices, gender dynamics, innovation uptake, and nutrition outcomes, drawing on diverse evidence to develop an integrated and practice-oriented perspective on food system resilience. In addition to the literature, the review is supplemented with descriptive evidence from a field survey of 1,711 indigenous fruits and vegetable farmers conducted by the authors and partners across eight West African countries in 2024. These data are presented only as illustrative context to enrich thematic discussions and are not subjected to statistical analysis, thereby preserving the review nature of this study. We also acknowledge that this is not a systematic review and therefore does not follow a reproducible process for literature inclusion or exclusion. The narrative review approach was intentionally adopted to allow for flexibility in integrating diverse sources, including peer-reviewed studies, technical reports, and practitioner insights, which are essential for capturing the multifaceted nature of indigenous crop processing and preservation. This approach provides a broad, practice-oriented perspective suited to the policy and applied focus of this paper.

3 Literature review

The literature on indigenous food crops and their postharvest handling in West Africa reveals a rich tapestry of traditional knowledge systems, evolving technologies, and persistent structural challenges. Scholars have consistently emphasized the nutritional, cultural, and ecological value of indigenous crops such as pearl millet, sorghum, cowpea, fonio, yam, and African leafy vegetables (Akinola et al., 2020; Rouamba et al., 2023). These crops are not only climate-resilient but also central to local diets and livelihoods, particularly among smallholder farmers and women-led enterprises.

Crucially, addressing the limitations of traditional preservation techniques, such as inconsistent hygiene, nutrient degradation and variable quality, is essential to safeguard nutrient integrity and harness the full nutritional potential of West Africa's indigenous crops. Traditional processing and preservation methods, including fermentation, sun-drying, roasting, soaking, and the use of ash or clay, have been widely documented as effective, low-cost strategies for extending shelf life and enhancing food safety (Aworh, 2008; Asogwa et al., 2017). These methods are deeply embedded in cultural practices and often passed down through generations, with women serving as key custodians of this knowledge. For instance, fermented products

like *dawadawa* (from African locust bean) and *ogi* (from maize or millet) not only improve digestibility and flavor but also serve as cultural markers in many communities (Akinola et al., 2020).

However, the literature also highlights significant constraints. Traditional methods, while accessible, are labor-intensive, time-consuming, and susceptible to contamination due to inadequate hygiene and infrastructure (Aworh, 2008). Moreover, the erosion of indigenous knowledge, driven by urbanization, generational shifts, and limited documentation, poses a threat to the continuity of these practices (Akinola et al., 2020).

In response, recent studies have explored the integration of modern technologies such as solar dryers, vacuum packaging, and improved fermentation starters to enhance efficiency, safety, and marketability (Kong et al., 2024; Sahu and Panda, 2018). These innovations offer promising avenues for reducing postharvest losses and improving the year-round availability of indigenous crops. Yet, adoption remains uneven due to cost barriers, limited technical capacity, and weak extension services (Rutta, 2022; Kaur and Watson, 2024).

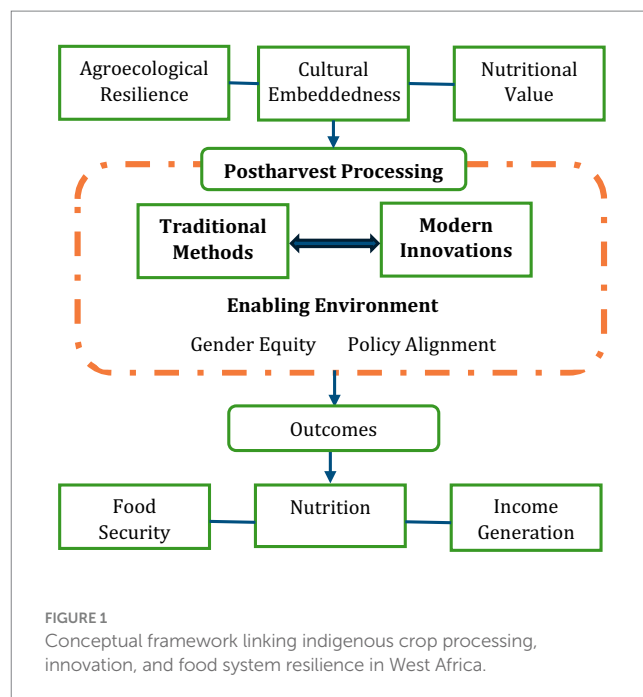
Comparative analyses suggest that hybrid approaches that combine traditional knowledge with context-appropriate modern techniques can yield optimal outcomes in terms of nutritional retention, shelf-life extension, and economic empowerment (Akinola et al., 2020; Misereor, 2022). Such models are particularly effective when co-developed with local communities and aligned with gender-sensitive value chain development.

Overall, the literature underscores the need for policy frameworks and investment strategies that recognize the dual value of indigenous knowledge and technological innovation. Strengthening research, documentation, and capacity building especially among youth and women emerges as a recurring recommendation for scaling up the utilization of indigenous crops in sustainable food systems.

4 Conceptual framework

Figure 1 positions indigenous food crops valued for their agroecological resilience, cultural embeddedness and nutrient richness, at the heart of resilient West African food systems. From this core, three pillars emerge. The core attributes of these crops include their ability to thrive under drought and low-input conditions, their deep integration into local foodways and ceremonies, and their rich micronutrient content. These attributes are sustained through processing pathways that draw on both traditional techniques, such as fermentation, sun-drying, roasting, and soaking, and modern innovations, including solar dryers, defined starter cultures, vacuum packaging, and mechanization. The successful integration of these pathways depends on a supportive enabling environment that prioritizes gender-responsive policies, capacity building, institutional support, infrastructure investment, and the development of market linkages and value-chain partnerships. Together, these factors drive the realization of the framework's desired outcomes, which include reducing postharvest losses, extending shelf-life, safeguarding or enhancing nutrient quality, and creating expanded income opportunities for smallholders and women processors.

This framework illustrates the interconnected roles of traditional processing methods and modern innovations in enhancing the utilization of indigenous crops. It highlights how agroecological resilience, cultural embeddedness, and nutritional value are mediated



through integrated postharvest practices, supported by enabling environments such as gender equity, policy alignment, and infrastructure, to achieve outcomes in food security, nutrition, and income generation.

4.1 Indigenous crops and agroecological resilience

Indigenous crops such as pearl millet, sorghum, fonio, cowpea, yam, and African leafy vegetables are deeply embedded in West Africa's rainfed farming systems. These crops are not only adapted to marginal soils and erratic rainfall but also support biodiversity and cultural identity (Misereor, 2022; Talabi et al., 2022). Their cultivation reflects a co-evolution of ecological adaptation and farmer-led selection, often involving multiple varieties to meet diverse production goals ranging from food and fodder to ceremonial use and market sale (Muyambo and Shava, 2021).

4.2 Traditional knowledge systems and postharvest practices

The framework recognizes traditional food processing and preservation as a form of indigenous knowledge, empirical, adaptive, and socially embedded. Techniques such as fermentation (*dawadawa*, *ogi*), sun-drying (okra, leafy greens), roasting (groundnuts, cereals), and the use of ash or clay for storage are not merely functional but also culturally significant. These practices are often gendered, with women playing a central role in knowledge transmission, innovation, and commercialization (Akinola et al., 2020).

Recent survey data collected from 1,711 indigenous fruits and vegetable farmers across eight West African countries further illustrate the persistence and importance of these traditional postharvest practices. While not the primary focus of this review,

these descriptive insights contextualize the literature and underscore the continued relevance of practices such as washing, drying, sorting, and storage. Washing clean was the most widely practiced value-added activity, reported by 70.3% of farmers, reflecting its central role in preparing produce for consumption, drying, storage, or sale. Drying, a critical preservation technique to extend shelf life and reduce spoilage, was practiced by 68.4% of farmers, particularly for leafy vegetables, okra, and fruits, as shown in Table 1. Sorting, carried out by 51.7% of farmers, ensured the removal of damaged or infested items, thereby enhancing quality and safety during storage or processing.

Other practices such as grinding (10.7%) and juicing (2.8%) were less common but remain important for specific crops, such as transforming leafy vegetables into powders or fruits into juices for direct consumption or local sale. Packaging (8.6%) and labeling (2.2%) were practiced by relatively few farmers, highlighting a gap in modern value addition practices that could enhance market opportunities. Storage (33.0%) and transport (35.0%) were also significant activities, underscoring their relevance for maintaining produce quality and facilitating market access.

4.3 Modernization and technological integration

Modernization and Technological Integration Studies demonstrate that solar drying and vacuum packaging significantly reduce microbial contamination and preserve nutrient quality in indigenous vegetables (Kong et al., 2024; Kaur and Watson, 2024). Controlled fermentation using defined starter cultures, such as *Lactobacillus plantarum*, has improved safety and consistency in dairy and cereal products (Praveen and Brogi, 2025). While traditional methods remain vital, they face limitations in terms of labor intensity, hygiene, and scalability (Asogwa et al., 2017). The framework incorporates the role of modern technologies, such as solar drying, vacuum packaging, improved fermentation starters, and mechanized milling, as tools for enhancing efficiency, safety, and value addition. The integration of these technologies with traditional practices is viewed not as a replacement but as a pathway to hybrid innovation that respects local contexts and enhances adoption.

4.4 Food and nutrition security outcomes

Food and Nutrition Security Outcomes Evidence from Erelu et al. (2023) suggests that fortification of foods with African indigenous vegetables can enhance micronutrient intake, particularly iron and vitamin A, thereby reducing hidden hunger. The framework links processing and preservation methods to broader food system outcomes. They contribute to nutritional quality by ensuring the retention or enhancement of micronutrients and improving bioavailability (Sharma et al., 2024). They also extend shelf-life and availability, thereby reducing seasonal gaps and minimizing postharvest losses (Lys, 2025; Yogita et al., 2024). In addition, these methods promote affordability and access, lowering costs for both rural and urban consumers by reducing spoilage and stabilizing supply chains. Finally, they support livelihoods, particularly for women and small-scale processors, by creating income-generating opportunities through the production and sale of safe, high-quality indigenous food products (Erelu et al., 2023; Laibuni et al., 2024; Jarman et al., 2023).

4.5 Enabling environment and policy Interface

Finally, the framework acknowledges the role of enabling institutions, policy, research, extension, and markets in shaping the viability of both traditional and modern approaches. It emphasizes the need for participatory innovation, investment in infrastructure, and the recognition of indigenous knowledge in formal food security strategies (Shibata, 2020). By mapping how crop attributes, processing pathways and enabling factors interconnect to drive food-security outcomes, this framework provides a clear roadmap for designing and scaling integrated interventions that strengthen West African food system resilience (Olabisi et al., 2022).

5 Traditional processing and preservation methods in West Africa

Traditional food processing and preservation techniques in West Africa are deeply interwoven with the region's ecological realities,

TABLE 1 Percentage of indigenous fruits and vegetable farmers engaging in various value-added activities across eight West African countries.

Value-added activity	Burkina Faso	Mali	Ivory coast	Niger	Nigeria	Ghana	Sierra Leone	Liberia	Average
Washing clean	91.6	97.7	9.8	79.3	91.1	76.3	95.2	21.3	70.3
Drying	87.9	98.5	19.5	48.3	59.8	52.6	81.0	100.0	68.4
Sorting	43.9	96.7	58.5	6.9	68.7	77.2	61.9	0.0	51.7
Juicing	0.9	10.2	0.0	1.7	8.9	0.9	0.0	0.0	2.8
Packaging	0.0	1.5	14.6	12.1	5.6	29.8	4.8	0.0	8.6
Grinding	0.0	66.8	0.0	0.0	10.1	3.5	0.0	0.0	10.7
Labeling	0.0	0.3	7.3	0.0	0.6	9.6	0.0	0.0	2.2
Storage	32.7	78.1	2.4	31.0	54.7	45.6	19.0	0.0	33.0
Transport	91.6	1.5	26.8	13.8	70.9	75.4	0.0	0.0	35.0
Number of farmers surveyed	151	398	150	139	250	289	151	183	213.9

Source: Authors' field survey (2024).

cultural heritage, and gendered labor systems (Akinola et al., 2020). These methods have evolved as adaptive strategies to extend shelf life, enhance palatability, and ensure year-round food availability in the absence of refrigeration or industrial infrastructure (Aworh, 2008; Asogwa et al., 2017). Below is an expanded overview of key techniques, enriched with region-specific examples:

5.1 Fermentation

Fermentation is a fundamental traditional processing method in West Africa, valued for its role in preserving perishable foods, enhancing nutritional quality, improving flavor, and supporting food safety. It operates primarily through the spontaneous activity of lactic acid bacteria, yeasts, and *Bacillus* species, often without standardized starter cultures (Lys, 2025). Widely consumed fermented foods include Ogi (Akamu), a maize, millet, or sorghum porridge commonly used as a weaning food in Benin and Nigeria (Afolabi et al., 2018); Dawadawa, a pungent, protein-rich seasoning derived from African locust bean (*Parkia biglobosa*) seeds and widely used in Nigeria, Ghana, and Burkina Faso (Ahmad et al., 2022); and Kenkey and Banku, fermented maize dough dishes popular in Ghana (Annan et al., 2015). Other notable examples are Gari, a detoxified cassava product produced through fermentation and roasting (Ngoualem Kégah and Ndjouenkeu, 2023); Pito and Burukutu, traditional alcoholic beverages made from sorghum or millet and consumed during festivals and social gatherings in northern Ghana and Nigeria (Avicor et al., 2015); and Nunu, a naturally fermented milk product (Akabanda et al., 2010).

Fermentation improves digestibility, reduces antinutritional compounds, increases vitamin levels (especially B-complex), and introduces probiotic benefits (Hlangwani et al., 2023). However, traditional practices have challenges including labor intensity, inconsistent quality, and food safety risks (Niyigaba et al., 2025). Emerging innovations such as controlled fermentation and use of beneficial starter cultures present opportunities to modernize traditional methods without displacing their cultural significance (Praveen and Brogi, 2025).

5.2 Drying

Drying is one of the most widely used and accessible traditional preservation methods in West Africa, particularly effective in extending the shelf life of perishable crops under hot climatic conditions. Sun-drying is commonly employed for okra, leafy vegetables, cassava chips (*kokonte*), and fruits by spreading them on mats or rooftops (Vaishnav et al., 2024). These techniques reduce moisture content to inhibit microbial growth, enabling households to store seasonal produce for dry-season consumption. However, sun drying has been shown to cause a reduction in nutrients such as β -carotene and ascorbic acid (Osunde and Makama, 2007; Owade et al., 2022; Ndawula et al., 2004). Exposure to solar radiation and UV rays, may be responsible for the loss of these nutrients (Ndawula et al., 2004). Despite being energy-efficient and low-cost, traditional drying methods are often labor-intensive and susceptible to contamination, prompting growing interest in improved options like solar dryers to enhance food safety and nutrient retention (Pandey et al., 2024).

5.3 Roasting and parboiling

Roasting and parboiling are traditional thermal processing techniques widely practiced in West Africa to improve the flavor, digestibility, and shelf stability of indigenous crops (Benhura et al., 2024; Ogwu et al., 2024). Roasting, typically applied to legumes like groundnuts and Bambara groundnuts, enhances aroma and reduces moisture content, making products more palatable and storage friendly (Ogwu et al., 2024). Parboiling, commonly used for rice and some legumes, involves soaking, steaming, and drying, which improves milling quality, shortens cooking time, and helps retain essential nutrients, particularly B-vitamins (Oghbaei and Prakash, 2010). Both methods contribute significantly to local food security by extending shelf life and facilitating ease of preparation, especially in settings with limited access to refrigeration or industrial processing (Asogwa et al., 2017; Benhura et al., 2024).

5.4 Soaking, germination, and malting

Soaking, germination, and malting are traditional pre-processing techniques widely used across West Africa to improve the nutritional quality and functional properties of indigenous grains and legumes (Laryea et al., 2024). Soaking softens hard seed coats, reduces cooking time, and leaches out antinutritional compounds such as phytates and tannins. Germination and malting where seeds are allowed to sprout, activate endogenous enzymes that enhance bioavailability of minerals, increase vitamin content (notably B-complex and C), and improve digestibility (Nkhata et al., 2018; Ikram et al., 2021). These methods are commonly applied in the preparation of traditional foods and beverages such as *kunu* and *malting sorghum pap* in Nigeria and Niger (Singh et al., 2015). Beyond their nutritional benefits, these techniques are simple, low-cost, and well-suited to resource-constrained contexts, though they require careful timing and hygiene to avoid spoilage or microbial contamination (Baskota, 2019).

5.5 Use of ash, clay, and botanical preservatives

Traditional preservative techniques in West Africa often utilize locally available natural materials such as ash, clay, and botanicals to extend shelf life and protect food from spoilage and pests. Ash, commonly from wood or crop residue, is applied to tubers like yam and sweet potato to absorb moisture and deter rot. Clay is used in the lining of granaries and storage containers to regulate humidity and temperature, particularly in Sahelian regions (Okparavero et al., 2024). Botanical preservatives like neem leaves, chili pepper, or dried lemon grass are mixed with stored grains such as millet, sorghum, or cowpea to repel insects and mold without the use of synthetic chemicals (Trivedi et al., 2018). These low-cost, environmentally friendly practices are critical in rural settings with limited access to refrigeration or industrial pest control.

These methods, while often labor-intensive, are contextually appropriate and environmentally sustainable (Asogwa et al., 2017). They form the backbone of rural food systems and offer a foundation for hybrid innovations that combine ancestral wisdom with modern food safety and value addition. At their best, these time-honored

methods like fermentation, drying, roasting, soaking and the use of natural preservatives have underpinned food security, cultural identity and local livelihoods across West Africa (Asogwa et al., 2017). Yet, the labor-intensity, quality variability and hygiene constraints that accompany artisanal processing point to the need for complementary solutions. In the next section, we turn to modern and innovative technologies such as solar-assisted drying, vacuum and modified-atmosphere packaging, controlled fermentation with defined starter cultures, mechanized milling and fortification strategies to illustrate how hybridizing ancestral wisdom with appropriate technological interventions can boost efficiency, safety and market competitiveness without sacrificing cultural resonance.

6 Modern and innovative processing and preservation techniques

In response to the labor intensity, variable quality and contamination risks of traditional methods, West African food systems are turning to modern innovations such as solar and cabinet dryers, vacuum/modified-atmosphere packaging, defined fermentation starters, mechanized milling, parboiling units and flash dryers, to boost efficiency, safety, nutrient retention and marketability (Kong et al., 2024). Although high costs, limited technical capacity and weak infrastructure have slowed uptake, aligning these tools with local knowledge and gender-responsive design can slash postharvest losses, ensure consistent product quality and empower smallholder farmers and women processors (Eloju et al., 2023; Sobowale et al., 2023). Emerging digital platforms are further enhancing these innovations by facilitating real-time monitoring of drying conditions, linking smallholder processors to urban and export markets, and improving traceability along value chains (Rutta, 2022). Public-private partnerships have also begun piloting cold chain solutions for perishable indigenous vegetables and dairy products, which, though costly, have shown potential to significantly extend shelf life and reduce food waste (Kaur and Watson, 2024). While West Africa is making incremental progress in integrating modern technologies into indigenous crop value chains, East Africa, particularly Kenya and Uganda, has made faster gains in digital market platforms and cold chain expansion, driven by stronger public-private partnerships and donor-led agri-tech ecosystems (Laibuni et al., 2024). However, West Africa holds a comparative advantage in its deeper repository of traditional knowledge and regionally embedded preservation techniques, offering a strong foundation for hybrid innovations that are culturally grounded and locally scalable.

6.1 Solar drying technologies

Solar dryers offer a significant upgrade over open-air sun drying by providing controlled drying environments that reduce microbial contamination, dust exposure, and nutrient degradation (Baidhe et al., 2024). In Ghana and other African countries, cabinet and tunnel solar dryers are being used to process leafy vegetables, okra, and cassava chips, resulting in improved product quality and longer shelf life (Baidhe et al., 2024). These dryers are often fabricated locally using wood, metal frames, and transparent polycarbonate sheets, making

them affordable and adaptable to rural contexts. Innovation uptake has been most successful when introduced through women-led cooperatives, where collective ownership and local fabrication enhance accessibility and maintenance (Eloju et al., 2023). From a nutrition perspective, studies show that solar drying retains more vitamins A and C in leafy vegetables compared with traditional sun-drying, helping to preserve the micronutrient density of indigenous foods (Kaur and Watson, 2024). By comparison, East African countries such as Uganda and Kenya have advanced the use of hybrid solar dryers integrating auxiliary energy, allowing for more reliable drying in regions with inconsistent sunshine (Kong et al., 2024). These designs have reduced postharvest losses of indigenous vegetables by up to 40%, a scale of efficiency not yet widely achieved in West Africa.

6.2 Vacuum packaging and modified atmosphere storage

Vacuum sealing and modified atmosphere packaging (MAP) are increasingly used for high-value indigenous products such as *dawadawa*, *gari*, and dried fruits. These technologies inhibit oxidation and microbial growth by removing or altering the composition of air in the packaging. Though currently limited to urban processors and export-oriented enterprises, they offer potential for scaling through cooperative models and shared processing hubs. Innovation uptake remains constrained by high equipment costs and limited technical know-how among rural processors (FAO, 2021). However, pilot programs that offer shared-use facilities or mobile vacuum sealers have improved access for smallholder processors in peri-urban areas (Rutta, 2022). These packaging innovations also preserve sensory and nutritional quality, particularly antioxidant activity and protein content, extending shelf life while enhancing the market value and dietary impact of indigenous products (Eloju et al., 2023; Jarman et al., 2023).

6.3 Controlled fermentation and starter cultures

To address the variability and safety concerns of spontaneous fermentation, research institutions in Nigeria, Ghana, and Benin have developed starter cultures for products like *ogi*, *nunu*, and *soumbala*. These cultures, often based on *Lactobacillus plantarum* or *Bacillus subtilis*, ensure consistent flavor, reduce fermentation time, and improve probiotic content. Their uptake has been facilitated by NGO-led trainings and food safety certification programs that target women-led enterprises (Kristjanson et al., 2017). Controlled fermentation also improves nutritional outcomes by increasing the bioavailability of iron, zinc, and B-vitamins, while introducing beneficial probiotics that support gut health (Hlangwani et al., 2023; Praveen and Brogi, 2025). This positions starter culture-based fermentation as a dual-benefit innovation that enhances both food safety and nutritional quality.

6.4 Mechanization and small-scale equipment

Mechanized equipment, such as cassava graters, hydraulic presses, flash dryers, and rice parboiling units, are being introduced to reduce

drudgery and increase throughput (Sobowale et al., 2023). In Nigeria, the mechanization of *gari* production has significantly improved processing efficiency and product uniformity (Obisesan et al., 2025). Similarly, mobile rice mills and solar-powered threshers are being piloted in Sierra Leone and Mali to support decentralized processing. The introduction of mechanization into the processing of cassava and yam chips in Benin and Togo resulted in an improvement in income and house livelihoods with benefits for women (Allogni et al., 2006).

6.5 Fortification and product innovation

Indigenous and underutilized crops can be used in food-to-food fortification of staple foods as a strategy to improve nutritional content of staple foods (Teye et al., 2020). The leaves of *Moringa oleifera* have been used to fortify maize, rice (Glover-Amengor et al., 2017) and pearl millet powder and porridge (Oluyimika et al., 2019), while *Moringa oleifera* seed flour has been used in the fortification of yam (Alabi et al., 2015). Fortification with *Moringa oleifera* leaves increased the levels of micronutrients (β -carotene, Cu, Zn, Mn, and Fe) (Glover-Amengor et al., 2017) while fortification with *Moringa oleifera* seed flour improved the protein, mineral content and texture of yam flour dough (Alabi et al., 2015). Innovative processing of indigenous crops includes the development of fortified and composite flours that incorporate indigenous crops (Ehis-Eriakha et al., 2025). For example, sorghum or millet flours are blended with soy or orange-fleshed sweet potato to enhance protein and vitamin A content (Jenfa et al., 2024; Mohammed Ali et al., 2024). These products are being promoted as complementary foods for infants and school feeding programs, with support from NGOs and national nutrition agencies. Value-added products that incorporate indigenous vegetables, have been developed. Breads and pastries have been fortified with *Solanum macrocarpon* L (egg plant), *Amaranthus viridis* L (Local Amaranth) and *Telfairia occidentalis* Hook. F. (fluted pumpkin) (Famuwagun et al., 2023). Consumers may obtain nutrition and health benefits from the addition of the indigenous vegetables to staple foods.

6.6 Digital tools and cold chain integration

Emerging digital platforms are being used to link smallholder processors to markets, provide real-time weather and drying data, and facilitate traceability. Cold chain technologies, though still limited, are being piloted for perishable indigenous vegetables and dairy products in peri-urban Ghana and Senegal, often through public-private partnerships (Zindi and Ndhlovu, 2025). While West Africa is still piloting cold chain technologies for indigenous vegetables, East Africa, particularly Kenya, has made more rapid progress through donor-driven agri-tech ecosystems and public-private partnerships (Laibuni et al., 2024). This has enabled wider uptake of digital traceability and cold storage, enhancing the competitiveness of indigenous produce in both local and export markets.

While these innovations offer transformative potential, their adoption is constrained by high upfront costs, limited technical capacity, and weak infrastructure. Bridging these gaps requires targeted investment, inclusive policy frameworks, and participatory technology development that aligns with local knowledge systems and gender dynamics.

7 Comparative analysis and integration of traditional and modern processing methods

This section compares traditional and modern processing methods and explores how they can be integrated to strengthen food systems in West Africa. Traditional techniques, such as fermentation, sun-drying, and roasting are accessible, culturally embedded, and well-suited to rural contexts, but they can be labor-intensive and inconsistent in quality (Aworh, 2023). Modern technologies, like solar dryers, vacuum packaging, and mechanized milling offer improved efficiency and food safety but are often costly and less accessible to smallholders (Baidhe et al., 2024). Integrated or hybrid approaches, such as using solar dryers for traditionally sun-dried vegetables or starter cultures for fermented foods, offer the best of both worlds. Successful models emphasize community engagement, gender-sensitive design, and access to training and infrastructure. For meaningful adoption, policies must support participatory innovation, capacity building, and market access to ensure that technological integration enhances rather than replaces traditional knowledge.

The coexistence of traditional and modern processing techniques in West Africa presents both a challenge and an opportunity (Kpadonou et al., 2025). A comparative analysis reveals distinct strengths and limitations in each approach, while integrated models offer promising pathways for enhancing food security, reducing postharvest losses, and supporting smallholder livelihoods. Table 2 shows the benefits of using traditional and modern methods for the processing and preservation of indigenous crops, while Table 3 summarizes the core features, advantages, and trade-offs across traditional, modern, and integrated processing approaches, offering a foundation for understanding hybrid models discussed in this section.

Traditional methods such as fermentation (*dawadawa*, *ogi*), sun-drying (okra, leafy greens), and roasting (groundnuts) are time-tested, environmentally sustainable, and well-suited to rural contexts. However, they often lack consistency and are constrained by labor intensity and exposure to contaminants. In contrast, modern technologies, such as solar dryers, vacuum packaging, and mechanized milling, offer efficiency, hygiene, and market readiness but may be inaccessible to smallholders without targeted support.

7.1 Integrated approaches: hybridizing knowledge systems

Emerging models across West Africa demonstrate the value of integrating traditional knowledge with modern innovations to improve the processing and preservation of indigenous crops (Akinola et al., 2020; Misereor, 2022). In Nigeria and Ghana, the use of starter cultures in the preparation of *ogi* and *numu* has enhanced product consistency and reduced fermentation time, while maintaining the traditional flavor profiles cherished by consumers. Similarly, women's cooperatives in Burkina Faso and northern Ghana have adopted solar-assisted drying technologies to process leafy vegetables and okra, significantly reducing spoilage and improving the quality of products destined for urban markets (Elohu et al., 2023; Kong et al., 2024). In Nigeria, hybrid cassava processing systems that combine traditional fermentation with mechanized grating, pressing, and roasting have boosted *gari* production, reducing labor demands and increasing efficiency. Additionally, the

TABLE 2 Relative benefits of modern and traditional processing and preservation techniques for indigenous crops.

Traditional and modern processing and preservation techniques	Benefits	Indigenous food crop	References
Fermentation	Production of Gari	Cassava	Aburime et al. (2019)
	Production of traditional beer (Dolo, Pito, Burukutu)	Sorghum	Sawadogo-Lingani et al. (2021)
	Reduction in anti-nutrients, increased phenolic content and antioxidant activity	Millet	Chauhan et al. (2024)
Sun-drying	Reduction in anti-nutrients, increased phenolic content and antioxidant activity	Millet	Chauhan et al. (2024)
Boiling and steeping	Production of Toubani. Flavor and Texture	Cowpea	Hongbete et al. (2017)
Boiling, sun drying and steeping	Production of Shea Butter	Shea Nuts	Aburime et al. (2019)
Smoking	Flavor enhancement and the prevention of spoilage	Shea kernels	Honfo et al. (2012)
Evaporative cooling	Extension of shelf-life	African Eggplants	Balogun and Ariahu (2020)

TABLE 3 Comparative matrix of traditional, modern, and integrated processing approaches.

Dimension	Traditional methods	Modern technologies	Integrated approaches
Accessibility	Low-cost, locally available	Capital-intensive, often urban-based	Community-based hubs with shared equipment
Labor intensity	High, especially for women	Reduced through mechanization	Gender-sensitive tools reduce drudgery, while preserving cultural roles
Food safety	Variable hygiene, risk of contamination	Improved through standardization	Traditional methods enhanced with hygiene protocols and packaging
Nutritional quality	Enhanced via fermentation, germination	Preserved through controlled environments	Hybrid methods retain nutrients and improve consistency
Cultural relevance	Deeply embedded in local foodways	May lack cultural resonance	Builds on traditional knowledge with modern efficiency
Scalability	Limited by manual processes	Scalable with infrastructure	Scalable through cooperative models and training

establishment of community processing hubs equipped with modern tools such as flash dryers and parboilers has enabled smallholders to process crops like fonio and millet while preserving traditional techniques and recipes ([Kaur and Watson, 2024](#)). These hybrid models are particularly successful when they are co-designed with local communities, integrate gender-sensitive approaches, and are reinforced through extension services and market linkages, ensuring both cultural relevance and economic viability ([FAO, 2021](#)).

7.2 Strategic considerations for integration

Scaling integrated processing systems in West Africa requires a supportive set of enabling factors that ensure both cultural relevance and sustainability ([Misereor, 2022](#); [FAO, 2021](#)). Participatory technology development is essential, with the active involvement of end-users, particularly women, in the design and adaptation of processing technologies to guarantee usability and cultural fit. Equally important is capacity building, which provides training in hygiene, equipment operation, and business skills to enhance adoption and long-term sustainability ([Ragasa et al., 2013](#)). Policy alignment also plays a critical role, as national food security strategies must formally recognize the value of traditional methods and promote their modernization through targeted subsidies, infrastructure development, and research investments ([Olabisi et al., 2022](#); [Kaur and Watson, 2024](#)). Finally, ensuring market access

through certification schemes, product branding, and cooperative marketing can allow traditionally processed indigenous products to meet the quality standards demanded by both urban and export markets, thereby boosting smallholder incomes and strengthening local food systems ([Elolu et al., 2023](#)).

8 Value addition for indigenous food crops

Harnessing traditional and modern food processing and preservations methods, indigenous food crops can be processed into innovative value-added products that would not have been possible, using only traditional methods. Turkey berries (*Solanum torvum*) have medicinal properties and parts of the plant and its fruits are used in traditional medicine ([Yousaf et al., 2013](#)). The ethanol extract of *Solanum torvum* berries has been shown to have anticancer properties. The combination of the processing methodologies allows for the production of *Solanum torvum* (Turkey berry) tea ([Asante et al., 2024b](#)). The use of freeze-drying technology allows for the production of freeze-dried Turkey berry, which can be ground and used as an ingredient in food products. The use of freeze-drying technology will produce a Turkey berry product of much better quality than can be produced by solar or oven drying. Turkey berry fruits and leaves added to food or consumed as tea or herbal infusion can be used in the treatment of anemia ([Asante et al., 2024a](#)).

Frafra potato (*Solenostemon rotundifolius*) an indigenous tuber grown in Northern Ghana and in Burkina Faso, can be processed into a flour and combined with wheat flour to make a composite flour that can be used in baking bread (Osei Tutu et al., 2019). The flour can be used for food processing beyond its use in baking (Osei Tutu et al., 2024). Modern processing techniques can be used to extract starch from Frafra potato with the potential for use in different food applications (Osei Tutu et al., 2023).

The use of indigenous crops in composite flour extends beyond Frafra potato. Sprouted finger millet flour combined with maize to form a composite flour, has been used to make a breakfast cereal (Acheampong et al., 2024). The use of modern food processing technologies, often in combination with traditional methods, provides new use opportunities and creates avenues for innovation, value-addition and entrepreneurship, with benefits throughout the value chains for the indigenous crops. In addition, the new uses of indigenous crops that are discovered through the uses of modern processing and preservation techniques, creates demand that smallholder farmers, especially women, can take advantage of, to improve upon their livelihoods.

9 Gender dynamics

Gender shapes who does the work, who controls the tools and who reaps the rewards in both ancestral and modern processing systems. Women perform the bulk of traditional tasks, cleaning, fermenting, drying and packaging, yet often lack decision-making authority, asset control and access to training. Those same power dynamics hinder their adoption of innovations like solar dryers or mechanized mills, as credit, equipment design and extension services rarely reflect their needs. Access to credit remains a major constraint, as many women lack collateral and face discriminatory lending practices (FAO, 2021). Land ownership is also unequally distributed, with customary norms limiting women's rights to control or inherit land in much of West Africa (Akinola et al., 2020). Furthermore, women's participation in extension programs is disproportionately low due to male-focused scheduling and limited representation of female extension agents (Ragasa et al., 2013; Kristjanson et al., 2017). These barriers collectively restrict women's ability to adopt labor-saving technologies and scale up agro-enterprises, despite their central role in indigenous crop processing (Kristjanson et al., 2017). Embedding gender-responsive approaches, co-designing tools with women, tailoring finance and training to their schedules, and ensuring they hold ownership and leadership, unlocks greater efficiency, food safety and livelihoods across indigenous crop value chains. Evidence from East Africa shows that targeted interventions, such as gender-responsive credit schemes in Kenya and Uganda, have enabled women processors to adopt solar dryers and mechanized mills more readily (Kristjanson et al., 2017; Ragasa et al., 2013). West Africa could draw on these models to reduce the persistent barriers that limit women's participation in technological innovations.

9.1 Women's roles, power relations, and local entrepreneurship in indigenous crop processing

Women are at the heart of traditional food processing and preservation systems in West Africa, playing a dominant role in

transforming indigenous crops into shelf-stable, marketable products (Akinola et al., 2020). Their labor spans a wide range of postharvest tasks, cleaning, drying, milling, pounding, fermenting, cooking, and packaging and is grounded in deep indigenous knowledge passed down through generations (Kristjanson et al., 2017; Misereor, 2022). Women are particularly adept at techniques like cassava fermentation, shea butter extraction, and the parboiling of rice, anchoring household food security through their influence on food preparation, storage, and utilization (Ragasa et al., 2013).

These activities also represent critical income-generating opportunities. In many communities, women operate informal microenterprises producing *dawadawa*, cassava flour, *ogi*, and sun-dried vegetables for local markets (Afolabi et al., 2018; Akabanda et al., 2010). Despite this, systemic inequities persist while women dominate labor and processing roles, men are more involved in commercial-scale activities particularly where mechanization is used or profit margins are higher, such as mechanical milling or industrial drying (Kristjanson et al., 2017).

Power relations embedded in these systems often disadvantage women. In patriarchal settings, men typically control income from processed goods, and women face barriers to land ownership, access to credit, and opportunities for training (FAO, 2021). Their limited participation in decision-making at household and institutional levels constrains their ability to scale enterprises or influence policy.

Addressing these gender-based disparities requires deliberate action. Gender-responsive policies must formally recognize women as processors and entrepreneurs and promote their land rights, cooperative membership, and legal protections (FAO, 2021). The design and dissemination of low-cost, gender-sensitive technologies such as pedal-powered grinders or solar dryers can reduce drudgery and expand productivity (Elo et al., 2023). Equally critical are tailored financial products, literacy and business training, and programs that facilitate access to formal markets through certification, branding, and cooperative networks (Ragasa et al., 2013; Kristjanson et al., 2017). Enabling women to fully participate and benefit from value-added processing is not only a matter of equity but also essential for strengthening local food systems and rural economies (Laibuni et al., 2024).

9.2 Gender considerations in modern technology adoption

Women drive most traditional postharvest work yet face major access barriers. Embedding gender-responsive design and delivery is crucial to ensure innovations like solar dryers or mechanized mills truly benefit women processors (FAO, 2021). One of the most pressing challenges is capital and asset control, as women often lack access to collateral or credit facilities designed to match the seasonal and small-scale nature of their processing activities (Kristjanson et al., 2017). They are also constrained by time and labor burdens, since training on new equipment and its upkeep frequently conflicts with their household and caregiving responsibilities. In addition, technical and information gaps persist because extension programs are often male-focused, held at times or locations that are inconvenient for women, thereby limiting their participation (Ragasa et al., 2013). Furthermore, ownership and decision-making norms rooted in patriarchal

structures frequently relegate women to the role of helpers rather than primary managers of processing equipment. Embedding gender-responsive design and delivery in technological innovations such as solar dryers and mechanized mills is therefore essential to ensure that women can overcome these barriers and derive equitable benefits from modernization efforts.

9.3 Gender-responsive interventions

Addressing gender disparities in indigenous crop processing and preservation requires a comprehensive approach that embeds women's needs and perspectives into every stage of innovation and policy (Nwankwo, 2025). One effective strategy is co-design and participatory trials, where women are involved from the outset in prototyping new technologies to ensure that ergonomics, processing capacity, and maintenance requirements align with their daily realities. Equally important is the promotion of group ownership and flexible finance through support for women's cooperatives to collectively purchase and manage equipment, alongside innovative financial models such as "pay-as-you-process" schemes or rotating credit arrangements that reflect seasonal income flows. Strengthening tailored training and extension services is also vital, with hands-on, modular workshops delivered at community venues during off-peak times, facilitated by female extension agents and experienced women processors who can act as peers and mentors. Finally, the advancement of gender-sensitive policies and finance mechanisms is critical; this includes advocating for subsidies or tax breaks on processing equipment targeted specifically at women entrepreneurs, and embedding gender criteria within agricultural innovation funds and procurement policies.

Given the central role of women in indigenous crop processing and preservation, addressing gender disparities is critical to achieving food security outcomes, as their empowerment directly influences availability, access, utilization, and stability within food systems.

10 Implications for food security

Integrated processing and preservation of indigenous crops strengthens food security along all four FAO dimensions. In terms of availability, methods such as solar drying, vacuum packaging, and improved storage reduce postharvest losses and extend shelf life, ensuring a year-round supply of staple grains, tubers, and vegetables while narrowing seasonal hunger gaps (Kpadonou et al., 2025; Kaimal et al., 2022). Improved access follows, as lower spoilage leads to reduced market prices and more reliable supply chains, allowing smallholder producers to secure stable incomes and enabling both rural and urban consumers to benefit from affordable, locally processed foods. Enhanced utilization is also achieved through techniques such as controlled fermentation, the development of composite flours, and food fortification, which preserve or boost micronutrient content and bioavailability, thereby addressing hidden hunger by improving diet quality and diversifying nutrient intake (Sharma et al., 2024). Finally, stability is reinforced through diversified processing options and value-added enterprises, especially

those led by women, which increase resilience against climate shocks and economic downturns by allowing households with multiple processing streams, both traditional and modern, to adapt more readily when one crop or market faces disruption.

To realize these gains at scale, policymakers and development partners must embed indigenous-crop processing into national food strategies, invest in decentralized processing hubs, and design gender-responsive finance and training programs. This holistic approach will underpin resilient, nutrition-sensitive food systems across West Africa.

11 Conclusion

By weaving together three interdependent pillars, ancestral processing techniques, context-appropriate modern technologies, and a supportive enabling environment, we can fully unleash the power of West Africa's indigenous food crops for resilient, nutrition-sensitive systems. Traditional methods such as fermentation, sun-drying, roasting and the use of botanicals preserve cultural identity, enhance micronutrient bioavailability and offer low-cost, community-driven solutions. Modern innovations, solar and cabinet dryers, vacuum/modified-atmosphere packaging, defined fermentation starters, mechanized milling and digital traceability, boost efficiency, consistency, safety and market competitiveness while honoring local know-how.

Realizing this vision demands an enabling environment that bridges policy, investment and social equity. Governments and partners must embed indigenous-crop processing in national food strategies, fund decentralized hubs, champion gender-responsive finance and training, and strengthen extension services. Together, these measures will reduce postharvest losses, expand year-round access to affordable, nutrient-rich foods and open new income streams, especially for women processors and smallholders. Anchored in tradition, energized by innovation and underpinned by coherent governance, integrated processing systems can drive a lasting transition toward resilient, inclusive and locally rooted food sovereignty across West Africa.

Author contributions

JGNA: Investigation, Writing – original draft, Conceptualization, Writing – review & editing, Methodology. MA: Investigation, Writing – review & editing, Writing – original draft, Conceptualization. JNA: Methodology, Conceptualization, Writing – original draft, Investigation, Writing – review & editing. FA: Investigation, Writing – review & editing, Conceptualization, Methodology, Writing – original draft. JK: Writing – review & editing, Investigation, Methodology, Writing – original draft, Conceptualization.

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