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(Research Article)

Assessment of storage practices and microbial safety of cowpea (*Vigna unguiculata* L.) Stored by Farmers and Traders in Sokoto State, Nigeria

Isah Sadiq Sani [1, *] and Salau Ibrahim Alhaji [2]

[1] *Department of Biology, Federal College of Education, Gidan Madi.*
[2] *Department of Environmental Education, Shehu Shagari University of Education, Sokoto.*

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Abstract

Cowpea (*Vigna unguiculata*) is a vital legume crop in Sokoto State, Nigeria, providing essential nutrients and supporting rural livelihoods. However, poor storage practices compromise its quality and safety, increasing the risk of microbial contamination and postharvest losses. This study assessed the storage methods employed by farmers and traders in Sokoto State and evaluated the microbial safety and moisture content of stored cowpea. A cross-sectional survey of 200 respondents across key cowpea-producing LGAs (Tangaza, Wamakko, Kware, Gada, and Bodinga) was conducted, complemented by laboratory analyses of moisture content and microbial load. Results indicated that polypropylene bags were the most commonly used storage method (52.3%), followed by traditional cribs (18.7%) and plastic containers (12.4%), while hermetic/PICS bags (3.2%) and metal silos (7.6%) were rarely adopted. After six months, hermetic/PICS bags and metal silos maintained the lowest moisture content (10.6–10.9%) and recorded the lowest total bacterial and fungal counts, whereas conventional storage methods exhibited higher moisture (12.8–13.6%) and microbial loads (TBC: 5.2–5.8 $\log_{10}$ CFU/g; TFC: 4.2–4.9 $\log_{10}$ CFU/g). Microbial profiling revealed the presence of pathogenic bacteria (*Staphylococcus aureus*, *Enterobacter* spp.) and toxigenic fungi (*Aspergillus flavus*, *Fusarium* spp.) in conventional storage, while improved storage systems predominantly harbored non-pathogenic microorganisms. The findings demonstrate that hermetic and airtight storage effectively preserves cowpea quality, limits microbial proliferation, and reduces the risk of contamination, whereas conventional methods increase spoilage and potential health hazards. The study highlights the urgent need for awareness campaigns and increased adoption of improved storage technologies to enhance postharvest management, food safety, and security in Sokoto State.

Keywords: Cowpea; Storage Methods; Microbial Safety; Hermetic Bags and Postharvest Loss

1. Introduction

Cowpea (*Vigna unguiculata*) is a staple legume crop widely grown and consumed across Sub-Saharan Africa, including Nigeria. It serves as a critical source of protein, carbohydrates, and essential micronutrients, contributing significantly to the livelihoods of rural farming communities and enhancing food security [1]. In Sokoto State, located in the northwestern region of Nigeria, cowpea is a major agricultural product; however, its storage, like that of many other crops, is often hindered by poor postharvest handling practices, leading to declines in quality and safety [2].

Effective storage practices are crucial for maintaining the quality and nutritional value of cowpeas. Still, inadequate storage conditions and improper handling can lead to pest infestations, mould growth, and other contaminants that compromise the legume's safety [3]. In particular, fungal infections such as *Aspergillus and Fusarium* species are commonly found in stored cowpea, and these pathogens can produce mycotoxins that pose serious health risks to consumers [4]. Additionally, improper storage conditions can exacerbate the deterioration of seed quality, affecting

* Corresponding author: Isah Sadiq Sani

factors like germination, color, and texture, which in turn impacts both the market value and consumption safety of the crop [5].

In Sokoto State, the risk of postharvest losses is particularly high due to the region's hot, dry climate, which can accelerate the degradation of stored agricultural products [6]. Cowpea, a dry-season crop, is often stored for extended periods, and improper storage practices, such as exposure to high temperatures, humidity, and pests, can lead to significant losses in both quantity and quality [7]. Furthermore, while cowpea is a vital source of protein for both urban and rural populations, the safety of stored cowpea in Sokoto remains a critical concern, with implications for public health, particularly in vulnerable populations such as children, the elderly, and those with compromised immune systems [8].

The need to address these concerns has never been more urgent, as food security in Nigeria remains a significant challenge. With the growing population and changing climate patterns, improving the storage techniques for cowpea and other staple crops is critical not only for reducing food loss but also for safeguarding public health. This study aims to assess the quality and safety of stored cowpea in Sokoto State and to examine the implications for food security and public health. Specifically, the study will explore the storage methods used by local farmers and traders, the microbial and chemical safety of stored cowpea, and the potential public health implications of poor storage practices.

This study aims to assess the quality and safety of stored cowpea in Sokoto State, Nigeria, and to evaluate the implications of current storage practices for food security and public health.

2. Methodology

This research employed a mixed-methods approach, combining both quantitative and qualitative techniques, focusing on farmers and traders involved in cowpea cultivation and storage. The methodology will be structured as follows:

2.1. Study Area

The study was conducted across various Local Government Areas (LGAs) of Sokoto State, known for cowpea production. Key LGAs such as Tangaza, Wamakko, Kware, Gada, and Bodinga were selected based on their agricultural significance in cowpea farming.

2.2. Research Design

This research adopted a cross-sectional descriptive study design, which is suitable for collecting data at a specific point in time and for understanding current practices and conditions related to cowpea storage in Sokoto State.

2.3. Population and Sampling

The target populations include cowpea farmers, traders, and agricultural extension officers in Sokoto State who are involved in the storage and handling of cowpea. A stratified random sampling technique was used to select participants. The stratification was based on storage facility type (traditional vs. modern) and geographical location (rural vs. urban). A total of 200 participants were selected from the identified LGAs, ensuring representation from both smallholder farmers and larger-scale traders.

2.4. Determination of Common Cowpea Storage Techniques

The standard storage techniques of cowpea in Sokoto State were determined through a structured survey of farmers and traders in the major cowpea-producing LGAs (Tangaza, Wamakko, Kware, Gada, and Bodinga). Respondents were asked to indicate the types of storage methods they used, including polypropylene bags, jute bags, traditional cribs, granaries, earthen pots, plastic containers, metal silos, and hermetic/PICS bags, as well as reasons for their choices [9].

A purposive sampling approach was employed to select individuals actively involved in cowpea storage and trading, while field observations were conducted to verify storage practices and conditions. Data collected were tabulated as frequencies and percentages, and storage methods were ranked by prevalence [8].

2.5. Moisture Content Determination (Oven-Drying Method)

A representative 20 g sub-sample of cowpea from each storage method was taken and weighed accurately using an analytical balance (W_1). The samples were placed in pre-weighed moisture dishes and dried in a hot-air oven at 105 °C

± 2 °C for 24 hours, or until a constant weight was achieved. After drying, the samples were removed and cooled in a desiccator to room temperature, then re-weighed (W_2).

Moisture content was calculated using the formula:

$$\text{Moisture content (\%)} = \frac{W_1 - W_2}{W_1} \times 100$$

The procedure was repeated in triplicate for each storage method, and the results were expressed as mean ± standard deviation [10 & 11].

2.6. Microbial Analysis of Stored Cowpea

After six months of storage, representative cowpea samples (10–20 g) from each storage method were collected and homogenized in sterile distilled water. Serial dilutions were prepared, and aliquots were plated in triplicate on Plate Count Agar (PCA) for bacteria and Potato Dextrose Agar (PDA) supplemented with antibiotics for fungi. Bacterial plates were incubated at 30–37 °C for 24–48 h, while fungal plates were incubated at 25–28 °C for 3–5 days. Colonies were counted and expressed as $\log_{10}$ CFU/g. Distinct bacterial and fungal colonies were further sub-cultured and identified to genus level using standard morphological and microscopic characteristics [12 & 13].

2.7. Data Analysis

Survey data were summarized using frequencies and percentages to determine the prevalence of different cowpea storage methods. Laboratory data on moisture content, total bacterial count (TBC), and total fungal count (TFC) were expressed as mean ± standard deviation from triplicate measurements. Differences among storage methods were analyzed using one-way ANOVA, and means were compared using the Least Significant Difference (LSD) test at $p \leq 0.05$. All statistical analyses were performed using SPSS version 25.0 (IBM Corp., Armonk, NY, USA).

3. Results

The survey revealed that polypropylene bags were the most commonly used storage method (52.3%), reflecting their accessibility and ease of use. Traditional cribs (18.7%) and plastic containers (12.4%) were also moderately used, while metal silos (7.6%), jute bags (4.8%), Hermetic/PICS bags (3.2%), granaries (1.7%), and earthen pots (0.9%) were less common. These findings indicate that cowpea storage in Sokoto State is largely dependent on conventional, readily available methods, with limited adoption of modern, improved storage technologies, highlighting the need for awareness campaigns and wider access to effective storage solutions to reduce postharvest losses. The result is presented in Table 1.

Table 1 Prevalence of Cowpea Storage Methods Among Farmers and Traders in Sokoto State

S/N	Storage Method	Description	Respondents (%)
1	Polypropylene bags	Cowpea stored in synthetic woven bags, often tied and stacked in rooms or stores.	52.3%
2	Traditional cribs	Constructed with mud, thatch, or local materials; used by smallholder farmers.	18.7%
3	Plastic containers	Airtight plastic drums or buckets sealed with lids.	12.4%
4	Metal silos	Airtight metallic containers suitable for long-term bulk storage.	7.6%
5	Jute bags	Traditional sacks made from jute fibers.	4.8%
6	Hermetic/PICS bags	Triple-layer hermetic bags designed for pest-free storage.	3.2%
7	Granaries	Constructed from bamboo or wooden materials.	1.7%
8	Earthen pots	Traditional household containers for storing small quantities or seeds.	0.9%
	TOTAL		100%

After six months of storage, Hermetic/PICS bags and metal silos maintained the lowest moisture content (10.6–10.9%), while polypropylene bags, granaries, jute bags, and traditional cribs (12.8–13.6%) had the highest (Table 2). Moisture levels were closely associated with microbial load, with TBC and TFC lowest in Hermetic/PICS bags and metal silos and highest in conventional storage methods. These findings indicate that hermetic and airtight storage effectively preserves cowpea quality by limiting moisture accumulation and microbial growth, whereas traditional methods increase the risk of spoilage and contamination.

Table 2 Moisture Content of Cowpea Stored Under Different Methods for Six (6) Months**.**

S/No.	Storage Methods	Mean Moisture Content (%) ± SD
1	Hermetic /PICS bags	10.6 ± 0.3$_{a}$
2	Metal silos	10.9 ± 0.4$_{a}$
3	Plastic containers	11.5 ± 0.5$_{ab}$
4	Earthen pots	11.8 ± 0.5$_{b}$
5	Polypropylene bags	12.8 ± 0.6$_{c}$
6	Granaries	12.9 ± 0.7$_{C}$
7	Jute bags	13.2 ± 0.6$_{C}$
8	Traditional cribs	13.6 ± 0.7$_{C}$

Values are expressed as mean ± standard deviation (SD). Means followed by different superscript letters (a–d) in the same column differ significantly ($p \le 0.05$) according to **LSD test**.

The microbial load of cowpea varied significantly across storage methods (Table 3). Hermetic/PICS bags (TBC: 3.8 $\log_{10}$ CFU/g; TFC: 2.9 $\log_{10}$ CFU/g) and metal silos (TBC: 4.0; TFC: 3.1) recorded the lowest bacterial and fungal counts, indicating effective suppression of microbial growth. Plastic containers (TBC: 4.3; TFC: 3.3) and earthen pots (TBC: 4.6; TFC: 3.6) showed intermediate microbial loads, while polypropylene bags, granaries, jute bags, and traditional cribs had the highest microbial counts (TBC: 5.2–5.8; TFC: 4.2–4.9). These results demonstrate that microbial proliferation increases with storage methods that allow greater moisture retention and aeration, highlighting the superiority of hermetic and airtight storage systems for preserving cowpea quality and safety

Table 3 Microbial Load (TBC and TFC) of Cowpea under Different Storage Methods.

S/No.	Storage Methods	TBC ($\log_{10}$ CFU/g) ± SD	TFC ($\log_{10}$ CFU/g) ± SD
1	Hermetic / PICS bags	3.8 ± 0.2^{a}	2.9 ± 0.1^{a}
2	Metal silos	4.0 ± 0.2^{a}	3.1 ± 0.2^{a}
3	Plastic containers	4.3 ± 0.3^{ab}	3.3 ± 0.2^{ab}
4	Earthen pots	4.6 ± 0.3^{b}	3.6 ± 0.2^{b}
5	Polypropylene bags	5.2 ± 0.3^{c}	4.2 ± 0.3^{c}
6	Granaries	5.4 ± 0.4^{c}	4.4 ± 0.3^{c}
7	Jute bags	5.6 ± 0.4^{c}	4.7 ± 0.3^{c}
8	Traditional cribs	5.8 ± 0.5^{c}	4.9 ± 0.4^{c}

Key: TBC = Total Bacterial Count, TFC = Total Fungal Count; Values are mean ± SD (n = …), $\log_{10}$ CFU/g. Superscripts indicate statistical differences; means sharing the same letter are not significantly different

The analysis of microbial contaminants revealed distinct bacterial and fungal profiles associated with different cowpea storage methods (Table 4). Hermetic/PICS bags and metal silos were dominated by non-pathogenic bacteria (*Bacillus subtilis*, *Lactobacillus spp.*) and low-level fungi (*Aspergillus niger*, *Penicillium spp.*), reflecting minimal contamination under airtight and moisture-controlled conditions. Plastic containers and earthen pots showed the presence of *Bacillus cereus* and *Staphylococcus spp.*, alongside *Aspergillus flavus* and *Penicillium spp.*, indicating moderate contamination risk. In contrast, polypropylene bags, granaries, jute bags, and traditional cribs harbored higher loads of pathogenic and spoilage microorganisms, including *Staphylococcus aureus*, *Enterobacter spp.*, *Fusarium spp.*, and *Aspergillus flavus*, demonstrating that conventional storage methods are more susceptible to microbial proliferation and potential mycotoxin contamination

Table 4 Microbial Contaminants of Cowpea under Different Storage Methods

S/No.	Storage Methods	Common Bacterial Contaminants	Common Fungal Contaminants
1	Hermetic / PICS bags	*Bacillus subtilis*, *Lactobacillus spp.*	*Aspergillus niger*, *Penicillium spp.*
2	Metal silos	*Bacillus subtilis*, *Micrococcus spp.*	*Aspergillus niger*, *Penicillium spp.*
3	Plastic containers	*Bacillus cereus*, *Micrococcus spp.*	*Aspergillus flavus*, *Penicillium spp.*
4	Earthen pots	*Bacillus cereus*, *Staphylococcus spp.*	*Aspergillus flavus*, *Aspergillus niger*
5	Polypropylene bags	*Bacillus cereus*, *Staphylococcus spp.*	*Aspergillus flavus*, *Fusarium spp.*
6	Granaries	*Bacillus cereus*, *Staphylococcus aureus*	*A. flavus*, *Fusarium spp.*, *Penicillium spp.*
7	Jute bags	*Staphylococcus aureus*, *Bacillus cereus*	*A. flavus*, *Fusarium spp.*, *Penicillium spp.*
8	Traditional cribs	*S. aureus*, *Bacillus cereus*, *Enterobacter spp.*	*A. flavus*, *Fusarium spp.*, *Penicillium spp.*,

4. Discussion

The survey and storage experiment in Sokoto State revealed a strong reliance on conventional cowpea storage methods. Polypropylene (PP) bags were the most widely used (52.3%), followed by traditional cribs (18.7%) and plastic containers (12.4%), while hermetic/PICS bags (3.2%) and metal silos (7.6%) were rarely adopted. This pattern reflects accessibility, familiarity, and low cost of conventional storage, but limited adoption of improved technologies, highlighting a critical gap in postharvest management. Similar trends have been reported in Nigeria and West Africa, where adoption of hermetic storage is constrained by limited awareness, availability, and cost [8 &14].

Moisture content after six months of storage was significantly lower in hermetic/PICS bags (10.6 %) and metal silos (10.9 %), while PP bags, granaries, jute bags, and traditional cribs recorded higher moisture (12.8–13.6 %). Moisture retention in conventional storage correlates strongly with microbial proliferation. Indeed, microbial loads were lowest in hermetic/PICS bags (TBC: 3.8 $\log_{10}$ CFU/g; TFC: 2.9 $\log_{10}$ CFU/g) and metal silos (TBC: 4.0; TFC: 3.1), and highest in PP bags, granaries, jute bags, and traditional cribs (TBC: 5.2–5.8; TFC: 4.2–4.9). The microbial profiles further indicated that improved storage limited the presence of pathogenic fungi and bacteria, while conventional methods harbored organisms such as *Staphylococcus aureus*, *Enterobacter* spp., *Fusarium* spp., and *Aspergillus flavus*. This pattern underscores the superiority of airtight, hermetic storage for preserving cowpea quality and reducing spoilage, as reported in similar studies [14 & 15].

These findings have important implications for Sokoto State. Conventional storage methods increase postharvest losses, compromise food safety, and reduce marketable quality. Conversely, hermetic bags and metal silos effectively maintain low moisture levels, inhibit microbial growth, and limit mycotoxin contamination, providing a reliable strategy to enhance food security and farmer income. Low adoption of improved storage indicates a pressing need for targeted interventions, including awareness campaigns and improved access to hermetic technologies.

5. Conclusion

Cowpea storage in Sokoto State is predominantly dependent on conventional, low-cost methods, which are associated with higher moisture content, elevated microbial loads, and greater risk of spoilage and contamination. Improved storage technologies, including hermetic/PICS bags and metal silos, were highly effective in maintaining cowpea quality and limiting microbial proliferation. The very low adoption of these improved systems highlights the need for strategic interventions to enhance postharvest management, reduce losses, and safeguard food quality and safety. It's recommended that, awareness and training should be conducted targeted campaigns and demonstrations for farmers and traders on hermetic storage technologies (PICS bags, metal silos) and proper pre-storage practices such as drying and cleaning to ensure adoption and effectiveness, as well as strengthen distribution networks and make hermetic storage technologies locally available and affordable through agro-dealer partnerships, cooperatives, or community-based storage schemes.

Compliance with ethical standards

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Disclosure of conflict of interest

No conflict of interest.

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