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Impact of storage practices on the quality and safety of maize in Kebbi State, Nigeria

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Abstract

Maize (*Zea mays* L.) is a key staple crop in Nigeria, yet postharvest storage practices significantly influence its quality and safety. This study evaluated the impact of storage methods on moisture content, microbial contamination, and aflatoxin levels in maize stored by farmers and traders in Kebbi State, Nigeria. A descriptive cross-sectional design was employed, integrating structured surveys, laboratory analyses, and statistical evaluation. Polypropylene bags were the most commonly used method, accounting for 30%, followed by granaries (26%), and traditional cribs (20%). Moisture content varied significantly ($p < 0.05$) across methods, with underground pits (17.0 ± 1.0%) and traditional cribs (16.2 ± 0.8%) showing the highest levels, whereas metal silos (12.5 ± 0.5%) and plastic containers (13.8 ± 0.7%) maintained the lowest. Total bacterial and fungal counts were highest in underground pits and traditional cribs and lowest in metal silos and plastic containers. Fungal species isolated included *Aspergillus flavus*, *A. niger*, *A. fumigatus*, *Fusarium moniliforme*, and *F. graminearum*, with prevalence correlating to storage conditions. Aflatoxin B1 was detected in 78–88% of maize samples, with the highest mean concentration in Yawuri (45.51 ± 96.31 µg/kg). Total aflatoxin levels varied significantly among locations ($p < 0.05$), indicating that storage practices directly influence mycotoxin accumulation. Findings highlight that traditional storage methods predispose maize to microbial proliferation and aflatoxin contamination, whereas modern systems, such as metal silos and sealed plastic containers, effectively preserve grain quality. The study underscores the need for improved storage technologies, proper drying, and stakeholder education to enhance maize safety, reduce postharvest losses, and strengthen food security in Kebbi State.

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

1. Introduction

Maize (*Zea mays* L.) is a staple crop of immense socio-economic importance, serving as a vital food and feed source worldwide. In Nigeria, maize plays a central role in food security and agricultural economics, contributing significantly to both [1]. However, the safety and quality of stored maize remain critical concerns due to post-harvest losses, contamination, and improper storage practices. Kebbi State, a prominent maize-producing region in Nigeria, faces unique challenges in ensuring maize quality and safety during storage, exacerbated by climatic conditions and limited infrastructure. These challenges pose significant public health risks, including exposure to mycotoxins and foodborne pathogens [2].

Maize storage in Kebbi State is often conducted under suboptimal conditions, leading to fungal contamination, insect infestation, and biochemical degradation. These factors compromise maize quality and present significant health hazards to consumers. Mycotoxins, particularly Aflatoxins produced by Aspergillus species, are a critical concern because they are carcinogenic and have been linked to adverse health effects, including immune suppression and stunted growth [3]. Additionally, limited awareness, poor storage infrastructure, and inadequate regulatory frameworks exacerbate the problem, putting large segments of the population at risk. Despite its significance, limited

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research has been conducted to comprehensively assess the quality and safety of stored maize in Kebbi State, highlighting a pressing gap in understanding and addressing this critical issue.

Conducting this research is imperative to mitigate the public health risks associated with maize storage in Kebbi State. The findings will provide insights into the current status of maize quality, storage practices, and contamination risks, enabling policymakers, farmers, and stakeholders to implement evidence-based interventions. Moreover, this research aligns with global and national goals to enhance food safety and security, as outlined in the United Nations Sustainable Development Goals (SDGs 2: Zero Hunger and 3: Good Health and Well-Being). By identifying the critical control points in maize storage and recommending practical strategies for improvement, the findings from the presence study will provide useful information to researchers, agricultural policymakers, Quarantine and extension workers, and ultimately to farmers, marketers, and consumers of maize. The objectives of the study are to examine storage practices commonly employed by farmers and traders in Kebbi State and analyze microbial and chemical contaminants in stored maize samples.

2. Methodology

2.1. Study Design

A descriptive cross-sectional study was employed, integrating quantitative and qualitative methods to assess the quality and safety of stored maize.

2.2. Sampling

The research was conducted in Kebbi State, Nigeria, focusing on key maize storage hubs, including rural and urban areas known for maize production and storage. The State has four emirates: Argungu, Gwandu, Yawuri, and Zuru. Each Emirate has between 4 and 10 local government areas [4]. For this study, three emirates were selected: Birnin Kebbi, Argungu, and Zuru. These areas represent diverse storage practices across rural and urban settings, providing a comprehensive view of the techniques in use. A systematic random sampling technique was used to sample stored maize from markets and stores in the selected local governments of the emirates. These were identified by local government agriculture departments and traditional authorities.

2.3. Identification of storage methods

A descriptive survey was used to collect data on standard maize storage methods in Kebbi State. Structured questionnaires were administered to farmers and traders, and respondents were asked to indicate the storage method they commonly used. The completed questionnaires were collected, and the responses were tallied to generate frequencies and percentages for each storage method. The results were presented in a frequency table.

2.4. Determination of Moisture Content of Stored Maize

The moisture content of maize stored under different storage methods for five months was determined using standard laboratory procedures. Composite maize samples were collected from each storage method at the end of the storage period. The samples were oven-dried at 105 °C until a constant weight was achieved following the AOAC [5] standard method. Moisture content was calculated using the weight-loss difference, and the values were recorded as mean ± standard deviation. A statistical comparison of storage methods was conducted to determine significant differences in moisture retention. These procedures were consistent with established techniques reported earlier [5 & 6].

2.5. Isolation and Identification of Fungi Associated with the Stored Maize in Kebbi State

The total bacterial count (TBC) and total fungal count (TFC) of maize stored under different storage methods were determined using standard microbiological procedures. Composite samples were aseptically collected from each storage method at the end of the five-month storage period. Ten grams of each sample were homogenized in sterile peptone water, and serial dilutions were prepared following Harrigan & McCance (2014). Aliquots of appropriate dilutions were plated on Nutrient Agar for bacteria and Potato Dextrose Agar (acidified with lactic acid) for fungi, according to APHA (2015) guidelines. The plates were incubated at 37 °C for 24–48 hours for bacteria and at 25–28 °C for 3–5 days for fungi. Colony-forming units were counted and expressed as $\log_{10}$ CFU/g. The mean microbial loads and standard deviations were calculated, and significant differences among storage methods were assessed. These procedures were consistent with techniques commonly used in cereal-storage microbiology [8].

2.6. Statistical Analysis

All numerical data generated from the study were analyzed using descriptive statistics and inferential tests. The mean and standard deviation were calculated for moisture content and microbial counts of maize stored using different methods. One-way Analysis of Variance (ANOVA) was performed to determine whether there were significant differences among storage methods. Where significant differences occurred ($p < 0.05$), Duncan's Multiple Range Test (DMRT) was used to separate and compare the means.

3. Results

The result in Table 1 shows the distribution of standard maize storage methods used in Kebbi State. Polypropylene bags were the most commonly used method, accounting for 30% of the total responses, followed by granaries (26%) and traditional cribs (20%). This indicates that most farmers and traders prefer methods that are relatively accessible and easy to manage.

Less commonly used storage methods include plastic containers (10%), metal silos (8%), earthen pots (4%), and underground pits (2%), suggesting that these methods might be less accessible, more expensive, or less familiar to most respondents. Overall, the results highlight a preference for simple and cost-effective storage methods among maize handlers in the region. At the same time, a smaller proportion of people use more advanced or less conventional methods.

Table 1 Common Maize Storage Methods in Kebbi State

S/No.	Storage Methods	Frequencies	Percentage (%)
1.	Traditional cribs	60	20.0
2.	Granary	78	26.0
3.	Polypropylene bags	90	30.0
4.	Plastic container	30	10.0
5.	Metal Silos	24	8.0
6.	Earthen pots	12	4.0
7.	Underground pits	6	2.0
	Total	300	100%

Table 2 presents the moisture content of maize stored under different methods for five months. Underground pits recorded the highest moisture content (17.0 ± 1.0%), indicating that maize stored in this method retained more moisture, potentially increasing the risk of spoilage or fungal growth. Traditional cribs (16.2 ± 0.8%) and granaries (15.8 ± 0.7%) also had relatively high moisture content, suggesting moderate effectiveness in reducing grain moisture.

Polypropylene bags (15.4 ± 0.6%) and earthen pots (14.9 ± 0.9%) showed intermediate moisture levels. In comparison, plastic containers (13.8 ± 0.7%) and metal silos (12.5 ± 0.5%) had the lowest moisture content, indicating superior performance in maintaining dry conditions and potentially prolonging storage life.

The superscript letters indicate statistically significant differences among the methods. For instance, metal silos (d) had significantly lower moisture than all other methods, while underground pits (a) had significantly higher moisture than the rest. Overall, storage methods that limit exposure to air and humidity, such as metal silos and plastic containers, were most effective at reducing moisture content in stored maize.

Table 2 Moisture Content of Maize Stored Under Different Methods for Five (5) Months.

S/No.	Storage Methods	Moisture Content (%) ± SD
1.	Traditional cribs	$16.2{\pm}0.8_b$
2.	Granary	$15.8{\pm}0.7_b$
3.	Polypropylene bags	$15.4{\pm}0.6_{bc}$
4.	Plastic container	$13.8{\pm}0.7_{cd}$
5.	Metal Silos	$12.5{\pm}0.5_d$
6.	Earthen pots	$14.9{\pm}0.9_c$
7.	Underground pits	$17.0{\pm}1.0_a$

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

The table shows the total bacterial count (TBC) and total fungal count (TFC) of maize stored under different storage methods. Underground pits recorded the highest microbial load, with TBC of 6.8 ± 0.4 $\log_{10}$ CFU/g and TFC of 6.2 ± 0.3 $\log_{10}$ CFU/g, indicating poor hygienic conditions and a higher risk of spoilage. Traditional cribs (TBC 6.4 ± 0.2; TFC 5.8 ± 0.3) and granaries (TBC 6.2 ± 0.3; TFC 5.6 ± 0.2) also exhibited high microbial counts, suggesting moderate effectiveness in controlling microbial growth.

Polypropylene bags (TBC 6.0 ± 0.3; TFC 5.4 ± 0.2) and earthen pots (TBC 5.7 ± 0.3; TFC 5.2 ± 0.2) had intermediate microbial levels, reflecting moderate protection against bacterial and fungal contamination. Plastic containers (TBC 5.2 ± 0.2; TFC 4.6 ± 0.2) and metal silos (TBC 4.8 ± 0.1; TFC 3.9 ± 0.2) recorded the lowest counts, demonstrating superior effectiveness in maintaining microbial safety.

The superscript letters indicate statistically significant differences, with metal silos (d) having significantly lower bacterial and fungal counts compared to all other methods, while underground pits (a) had the highest counts. Overall, storage methods that reduce moisture and limit exposure to contaminants, such as metal silos and plastic containers, were most effective in controlling microbial proliferation in stored maize.

Table 3 Total Bacterial and Fungal Counts of Maize Across Different Storage Methods.

S/No.	Storage Methods	TBC ($\log_{10}$ CFU/g)	TFC ($\log_{10}$ CFU/g)
1	Metal Silos	4.8 ± 0.1^d	3.9 ± 0.2^d
2	Plastic container	5.2 ± 0.2^c	4.6 ± 0.2^c
3	Earthen pots	5.7 ± 0.3^{bc}	5.2 ± 0.2^{bc}
4	Polypropylene bags	6.0 ± 0.3^b	5.4 ± 0.2^b
5	Granary	6.2 ± 0.3^{ab}	5.6 ± 0.2^{ab}
6	Traditional cribs	6.4 ± 0.2^a	5.8 ± 0.3^a
7	Underground pits	6.8 ± 0.4^a	6.2 ± 0.3^a

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 table presents the fungal contaminants identified in maize stored using different methods in Kebbi State. Underground pits had the highest total fungal count (54 isolates), indicating that this storage method is highly susceptible to fungal infestation. Earthen pots (39 isolates) and metal silos also showed substantial fungal presence, though at lower levels than in underground pits.

Traditional cribs (27 isolates) and granaries (24 isolates) showed moderate fungal contamination, while plastic containers (19 isolates) and polypropylene bags (11 isolates) had the lowest fungal counts, suggesting better protection against fungal growth. Among the fungal species, *Aspergillus flavus*, A. *niger*, and *Fusarium graminearum* were commonly isolated across most storage methods, highlighting their prevalence in stored maize and potential risk for mycotoxin contamination. Overall, storage methods that limit moisture and environmental exposure such as polypropylene bags and plastic containers were most effective in minimizing fungal contamination, whereas methods like underground pits and earthen pots provided conditions favorable for fungal proliferation.

Table 4 Fungal Contaminants in Maize Stored by Different Methods in Kebbi State

S/No.	Storage Methods	*Aspergillus flavus*	*A. niger*	*A. fumigatus*	*Fusarium moniliforme*	*F. graminearum*	Total Fungal Count
1	Polypropylene bags	3	2	0	2	4	11
2	Plastic container	6	5	0	2	6	19
3	Granary	7	6	2	4	5	24
4	Traditional cribs	6	4	3	6	8	27
5	Metal Silos	8	6	2	6	8	30
6	Earthen pots	11	9	4	2	13	39
7	Underground pits	11	9	6	8	20	54

Values indicate the number of fungal isolates recovered from stored maize samples. Total fungal load is the sum across all species. Highest values are highlighted

The table shows aflatoxin levels (µg/kg) in maize samples collected from three Emirate Councils. **AFB1**, the most prevalent and toxic aflatoxin, was detected in 78% of samples in Gwandu, 88% in Argungu, and 88% in Yawuri. Yawuri recorded the highest mean AFB1 level (45.51 ± 96.31 µg/kg), followed by Gwandu (38.36 ± 60.42 µg/kg) and Argungu (29.76 ± 38.63 µg/kg), indicating a substantial risk of contamination. Other aflatoxins (AFB2, AFG1, AFG2) were also present, though at lower frequencies and concentrations. Notably, AFG1 in Argungu had the lowest mean (7.50 ± 13.71 µg/kg), while Yawuri and Gwandu had higher means for AFB2 and AFG1, showing variation in aflatoxin profiles across locations. The total aflatoxin levels followed a similar trend, with Gwandu (84.85 ± 123.87 µg/kg) and Yawuri (81.67 ± 141.74 µg/kg) recording higher contamination than Argungu (53.11 ± 80.11 µg/kg). The superscript letters indicate statistically significant differences, suggesting that aflatoxin contamination varies across emirates.

Overall, these results highlight widespread aflatoxin contamination in maize across the region, with some locations exhibiting high levels that could pose serious food safety and health risks.

Table 5 Aflatoxin Levels (µg/kg) in Maize Samples from Three Emirate Councils

Aflatoxins	Emirate	Frequency (n/50, %)	Range (µg/kg)	Mean ± SD (µg/kg)
AFB1	Gwandu	39/50 (78%)	1.0–211.0	38.36 ± 60.42[ab]
	Argungu	44/50 (88%)	0.3–116	29.76 ± 38.63[b]
	Yawuri	44/50 (88%)	0.7–252.5	45.51 ± 96.31[a]
AFB2	Gwandu	31/50 (62%)	0.1–56.0	12.74 ± 17.65[ab]
	Argungu	41/50 (82%)	0.2–68	14.06 ± 20.16[b]
	Yawuri	38/50 (76%)	0.1–91.0	15.09 ± 17.00[ab]
AFG1	Gwandu	26/50 (52%)	0.5–83.0	14.31 ± 28.44[a]
	Argungu	36/50 (72%)	0.3–41	7.50 ± 13.71[b]
	Yawuri	29/50 (58%)	0.3–76.8	14.08 ± 15.51[ab]
AFG2	Gwandu	21/50 (42%)	1.2–12.0	5.34 ± 7.92[a]
	Argungu	16/50 (32%)	0.3–10	1.08 ± 2.67[b]
	Yawuri	29/50 (58%)	1.0–23.0	3.28 ± 6.57[a]
Total AF	Gwandu	39/50 (78%)	0.1–211	84.85 ± 123.87[a]

	Argungu	44/50 (88%)	0.2–116	53.11 ± 80.11^{b}
	Yawuri	44/50 (88%)	0.1–252.5	81.67 ± 141.74^{a}

Superscript letters (a, b, ab) indicate statistical differences (ANOVA, $p < 0.05$)

4. Discussion

The findings of this study provide critical insights into maize storage practices, moisture dynamics, microbial contamination, and the prevalence of aflatoxin in Kebbi State. The study revealed that maize is predominantly stored using polypropylene bags, granaries, and traditional cribs, reflecting a preference for storage methods that are accessible, affordable, and manageable by smallholder farmers. Less frequently used techniques, such as metal silos, plastic containers, earthen pots, and underground pits, may be limited by higher costs, greater complexity, or limited availability, consistent with reports from similar agrarian communities in which resource constraints influence storage choices [9, 10, 11].

Moisture content analysis showed significant variation across storage methods. Maize stored in underground pits and traditional cribs retained the highest moisture levels, whereas metal silos and plastic containers had the lowest. High moisture content in stored maize is a significant factor predisposing grains to microbial proliferation and postharvest deterioration. Storage methods that effectively limit moisture uptake, such as hermetic or sealed containers, reduce spoilage and improve shelf life. These findings align with previous studies indicating that proper moisture management is a key determinant of storage quality and food safety [12].

Microbial analysis revealed that total bacterial and fungal counts varied significantly with storage method. Underground pits and traditional cribs exhibited the highest microbial loads, while metal silos and plastic containers had the lowest. The trend observed in fungal contamination mirrors that of bacterial counts, with underground pits and earthen pots supporting higher fungal populations, including species such as *Aspergillus flavus*, *A. niger*, *A. fumigatus*, *Fusarium moniliforme*, and *F. graminearum*. These fungi are recognized for their ability to produce mycotoxins, which pose significant risks to human and animal health [12, 13]. The prevalence of these fungi under less-protected storage conditions underscores the importance of improved storage technologies for reducing microbial hazards.

Aflatoxin analysis further emphasized the public health risk associated with inadequate storage. Aflatoxin B1, the most toxic and carcinogenic form, was detected at high frequencies across all sampling locations, with some samples exceeding internationally accepted safety limits. Total aflatoxin levels were highest in areas with traditional storage methods, indicating that poor storage infrastructure contributes directly to mycotoxin accumulation [13]. The observed variation in aflatoxin contamination across locations highlights the influence of local environmental conditions, storage duration, and handling practices on mycotoxin development [14].

Overall, the results demonstrate a clear relationship between storage methods, moisture content, microbial load, and aflatoxin contamination. Storage systems that minimize grain exposure to moisture and environmental contaminants, such as metal silos and sealed plastic containers, are most effective in preserving maize quality and ensuring food safety. Conversely, traditional and low-cost storage methods, while widely used, predispose maize to microbial proliferation and mycotoxin contamination, posing a risk to both food security and public health. These findings reinforce the need for targeted interventions, including farmer education, adoption of improved storage technologies, and regular monitoring of maize quality to mitigate postharvest losses and health hazards

5. Conclusion

This study demonstrates that maize storage practices in Kebbi State significantly influence grain quality, microbial safety, and mycotoxin contamination. Traditional storage methods, such as underground pits, cribs, and granaries, were associated with higher moisture content, elevated bacterial and fungal loads, and greater aflatoxin accumulation, posing serious risks to food safety and public health. In contrast, modern storage systems, including metal silos and plastic containers, effectively maintain lower moisture levels and minimise microbial proliferation and mycotoxin contamination. These findings highlight the critical role of improved storage technologies in enhancing maize safety, reducing postharvest losses, and supporting food security in the region. It is recommended that farmers and traders adopt improved storage technologies, such as metal silos, hermetic bags, or sealed plastic containers, alongside proper drying practices, to minimise moisture uptake and microbial contamination. Additionally, capacity-building programs should be implemented to educate stakeholders on safe storage practices and the health risks associated with aflatoxin contamination.

Compliance with ethical standards

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Disclosure of conflict of interest

No conflict of interest to be disclosed.

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