

PERCEPTIONS, PRACTICES, AND HEALTH RISK AWARENESS RELATED TO MOLD CONTAMINATION OF AGRICULTURAL COMMODITIES AMONG HOUSEHOLDS IN JIGAWA STATE, NIGERIA

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ABSTRACT

Mold contamination of agricultural commodities poses a significant food safety and public health challenge in northern Nigeria, where climatic conditions and traditional post-harvest practices prevail. This study assessed household perceptions, practices, and health risk awareness related to mold contamination in Jigawa State, Nigeria, using a cross-sectional mixed-methods design. Quantitative data were collected from 400 households across agro-ecological zones, complemented by Focus Group Discussions, Key Informant Interviews, and observational assessments. Data were analyzed using descriptive statistics, chi-square tests, and multivariate logistic regression. Results showed that most households identified mold contamination using visible indicators such as dark spots (78.0%), discoloration (71.0%), and unpleasant odor (64.0%), with limited recognition of invisible mycotoxin risks. Although moisture (81.5%) and climatic conditions (76.0%) were widely perceived as major causes of mold development, only 53.0% of households acknowledged poor post-harvest handling as a contributing factor. Logistic regression analysis revealed that insect infestation (OR = 2.31), traditional storage methods (OR = 2.48), poor post-harvest handling (OR = 2.05), and prolonged storage duration (OR = 1.89) significantly increased the likelihood of mold contamination ($p < 0.01$). While general awareness of mold existed, only 29.5% of households demonstrated good knowledge of associated health risks. Education level, income, gender, and household size were significantly associated with mold-related knowledge, and good knowledge reduced the odds of mold contamination by 52% (OR = 0.48). Qualitative evidence from focus group discussions, key informant interviews, and field observations showed that households relied mainly on visual indicators to detect mold, underestimated the health risks of invisible mycotoxins, and attributed contamination largely to uncontrollable climatic factors. Traditional storage practices, poor ventilation, inadequate drying, and insect infestation were commonly observed, reinforcing quantitative evidence that modifiable household behaviors and structural constraints play a major role in mold contamination. The study highlights substantial knowledge and practice gaps that sustain household exposure to mold and mycotoxins in Jigawa State, underscoring the need for targeted education, improved storage technologies, and strengthened extension and public health interventions.

Keywords: Mold contamination; Mycotoxins; Post-harvest practices; Food safety; Jigawa State, Nigeria

INTRODUCTION

Mold contamination of agricultural commodities remains a critical food safety and public health challenge globally, particularly in low- and middle-income countries where climatic conditions, post-harvest losses, and informal food systems prevail. Filamentous fungi such as *Aspergillus*, *Fusarium*, and *Penicillium* commonly infest staple crops including maize, millet, sorghum, groundnuts, and rice, especially under conditions of high temperature, humidity, and inadequate storage (Ezekiel et al., 2021; Bello et al., 2024). Beyond visible spoilage, molds pose serious health risks by producing mycotoxins, toxic secondary metabolites that can cause acute and chronic health effects in humans and animals.

Globally, exposure to mycotoxins has been associated with liver cancer, immune suppression, impaired child growth, reproductive disorders, and increased susceptibility to infectious diseases (WHO, 2023; Adekoya et al., 2022). The Food and Agriculture Organization estimates that up to 25–40% of food crops worldwide are contaminated with mycotoxins annually, with the burden disproportionately affecting sub-Saharan Africa due to limited regulatory enforcement and poor post-harvest infrastructure (FAO, 2022). In recent years, climate change has further exacerbated the risk of mold contamination by altering rainfall patterns, increasing temperatures, and prolonging storage periods, thereby expanding fungal ecological niches (Battilani et al., 2023). In many rural settings, perceptions and practices surrounding mold contamination are shaped more by visual cues and cultural norms than by scientific understanding of fungal growth and toxin production. While visible mold is often recognized as undesirable, invisible contamination and delayed health consequences are poorly understood (Sani et al., 2023). Studies from South Asia and sub-Saharan Africa show that farmers may consume or sell partially moldy produce because of economic pressure, food insecurity, or misconceptions about safety after cooking or drying (Kyei et al., 2021; Nji et al., 2024).

In Nigeria, several studies have documented widespread fungal contamination and mycotoxin presence in staple foods across agro-ecological zones, including the Sudan and Sahel savannah regions (Ezekiel et al., 2021; Oyedele et al., 2022). Northern Nigeria, where Jigawa State is located, is particularly vulnerable because of traditional sun-drying methods, the use of porous storage materials, limited access to hermetic storage technologies, and low extension coverage (Bello et al., 2024). Despite growing scientific evidence on the health risks of mold and mycotoxin

exposure, empirical research remains limited on how rural households perceive mold contamination, how these perceptions shape food handling and storage practices, and the extent to which communities recognize these health risks.

Mold contamination of agricultural commodities represents a persistent but under-recognized public health and food safety problem in Jigawa State, Nigeria. Although the state is a major producer of cereals and legumes, post-harvest handling and storage practices remain largely traditional and poorly regulated. As a result, staple foods households consume daily are often exposed to conditions that favor fungal growth and mycotoxin production. Existing studies in Nigeria have largely focused on laboratory detection of fungal species and mycotoxin levels in food products, with limited attention to household-level perceptions, behavioral practices, and risk awareness (Ezekiel et al., 2021; Oyedele et al., 2022). Consequently, scientific knowledge and community practices are disconnected. Many households rely on visual assessment to judge food safety, often underestimating invisible contamination and long-term health consequences, particularly for children and pregnant women (Sani et al., 2023). Furthermore, poverty, food insecurity, and limited access to extension services compel households to consume or market mold-affected commodities rather than discard them, thereby increasing exposure risks. The absence of localized behavioral evidence hampers the effectiveness of food safety policies and public health interventions in the state. Without empirical data on perceptions, practices, and health risk awareness, interventions may fail to address the underlying behavioral and socio-cultural drivers of mold exposure. Understanding local perceptions and practices is critical to designing effective, culturally appropriate interventions to reduce mold contamination and associated health risks. This study therefore investigates perceptions, practices, and health risk awareness related to mold contamination of agricultural commodities among households in Jigawa State, Nigeria. It situates the findings within existing scientific and public health literature. This study addresses this gap by systematically examining how households in Jigawa State perceive mold contamination, the practices they use to handle and store agricultural commodities, and their awareness of associated health risks.

This study aims to assess perceptions, practices, and health risk awareness related to mold contamination of agricultural commodities among households in Jigawa State, Nigeria. With a view to examining household perceptions of mold contamination in commonly consumed agricultural commodities in Jigawa State, assessing post-harvest handling and storage practices that influence mold development at the household level, evaluate awareness and understanding of the health risks associated with mold and mycotoxin exposure, and identifying socio-economic and environmental factors influencing mold-related practices and risk perception.

MATERIALS AND METHODS

Study Area and Population

The study was conducted in Jigawa State, north-western Nigeria, extending approximately from 10°53'11.5594"N to 13°01'21.6755"N latitude and 8°02'31.9187"E to 10°36'46.4052"E longitude. Jigawa State shares boundaries with Kano and Katsina States to the west, Bauchi State to the east, Yobe State to the northeast, and the Republic of Niger to the north. The state lies predominantly within the Sudan and Sahel savannah agro-

ecological zones, which are characterized by semi-arid climatic conditions, low to moderate annual rainfall, and prolonged dry seasons (Adebayo et al., 2021; Nigerian Meteorological Agency [NiMet], 2023).

Annual rainfall in Jigawa State ranges from 500 to 800 mm, concentrated between June and September, while temperatures remain high year-round, often exceeding 35 °C during the dry season. These climatic conditions, combined with traditional post-harvest practices such as sun-drying on bare ground and storage in woven polypropylene sacks, create a favorable environment for fungal growth and mycotoxin production, particularly aflatoxins and fumonisins (Bandyopadhyay et al., 2022; Oyedele et al., 2024).

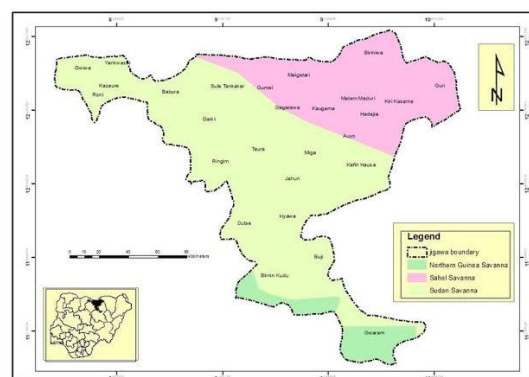


Figure 1: Jigawa State Map showing Agro-ecological Zone.
Source: Generated from Agro-ecological map of Nigeria, 2025

Research Design

A cross-sectional mixed-methods research design was adopted for this study. The quantitative component involved a household-based survey using structured questionnaires to generate measurable data on perceptions, knowledge, storage practices, and awareness of health risks related to mold contamination. The qualitative component comprised Focus Group Discussions (FGDs) and Key Informant Interviews (KIIs) conducted with farmers, extension workers, public health personnel, and community leaders.

The mixed-methods approach was considered appropriate because mold contamination is a multifaceted environmental health issue influenced by behavioral, socio-economic, and environmental factors. Combining quantitative and qualitative methods enabled triangulation of findings, improved validity, and deeper contextual understanding of household practices and perceptions (Creswell & Plano Clark, 2018; Molina-Azorin, 2016). This design is widely applied in food safety, environmental health, and behavioral risk studies in developing-country contexts.

Study Population

The target population comprised household heads and primary food handlers (farmers, traders, and women responsible for food storage and processing), Agricultural extension officers and community development agents, public health personnel (primary health care workers and community health extension workers), and community leaders and food processors/vendors.

These groups were selected because they either directly engage in post-harvest handling and storage practices or influence food safety awareness and health outcomes within communities.

Sampling Frame and Sampling Techniques

A multistage sampling technique was used to select households from different agro-ecological environments in Jigawa State. The sampling procedure was designed to capture variation in climatic conditions, agricultural activities, post-harvest handling, and household storage practices across the state. Because the agro-ecological zones are not equally distributed spatially, the sampling framework did not assume equal representation of the Sahel, Sudan, and Northern Guinea Savannah zones.

Stage One: Agro-Ecological Stratification

Jigawa State was stratified into three agro-ecological environments: **Sahel Savannah, Sudan Savannah, and Northern Guinea Savannah**. The Sudan Savannah is the dominant ecological environment in the state, while the Sahel Savannah occurs mainly in the north. The Northern Guinea Savannah occupies a relatively limited area in the southern part of the state, particularly within parts of Gwaram Local Government Area and adjoining areas. Consequently, the ecological zones were treated as geographically unequal strata rather than as three equally sized areas.

The stratification ensured that households from the major ecological environments were included in the study and that differences in environmental conditions and household practices could be examined. The final sample therefore included households from the Sahel, Sudan, and Guinea Savannah environments, consistent with the study area's ecological distribution.

Stage Two: Selection of Study Communities

Within the identified ecological strata, study communities were purposively selected based on their agricultural importance, household involvement in the production and storage of agricultural commodities, occurrence of household-level post-harvest activities, and relevance to the study objectives. Communities were also selected to provide geographical coverage across different ecological environments, rather than concentrating the study in a single part of the state.

The selected communities included **Damau, Kwari, Guna A. Lunga, Gangawa, Yan Kunama, Garin Hassan, Kukayesku, and Zingaram**. These communities provided coverage across the ecological settings represented in the study and enabled comparison of household perceptions, practices, and health-risk awareness under different environmental conditions.

Stage Three: Selection of Households

The study selected 400 households for the quantitative survey. The household was the principal sampling unit because decisions about the handling, drying, storage, processing, and consumption of agricultural commodities are commonly made at the household level. Household heads or persons primarily responsible for food handling and storage were targeted for questionnaire administration.

The distribution of respondents across the ecological environments was used to capture differences in household knowledge and perceptions. The results subsequently showed variation in mold-related knowledge across the three environments, with good knowledge reported among **67.7% of households in the Sahel Savannah, 74.8% in the Sudan Savannah, and 79.3% in the Northern Guinea Savannah**. This variation demonstrates the importance of retaining ecological stratification in the study design.

Stage Four: Qualitative Sampling

For the qualitative component, purposive sampling identified participants with direct experience or specialized knowledge of agricultural production, post-harvest handling, food storage, and community health. We conducted Focus Group Discussions (FGDs) separately with male and female participants to facilitate open discussion of household practices, perceptions, traditional knowledge, and perceived health effects of mold-contaminated commodities. Each FGD consisted of approximately **8–12 participants**.

Key Informant Interviews (KIIs) were conducted with agricultural extension personnel, public health workers, and community leaders. These participants provided information on post-harvest practices, community awareness, extension services, food-safety concerns, and institutional responses to mold contamination.

The combination of quantitative household sampling and purposive qualitative sampling allowed the study to capture both the measurable distribution of perceptions and practices and the contextual explanations underlying household behavior.

Overall, the sampling framework was designed to address the unequal geographical distribution of the agro-ecological environments in Jigawa State. In particular, the Northern Guinea Savannah was not treated as occupying an area equivalent to the much larger Sudan Savannah. The approach therefore sought to avoid over-representation of the limited Guinea Savannah area while ensuring that the Sahel, Sudan, and Guinea environments relevant to household mold-contamination risks were represented in the study.

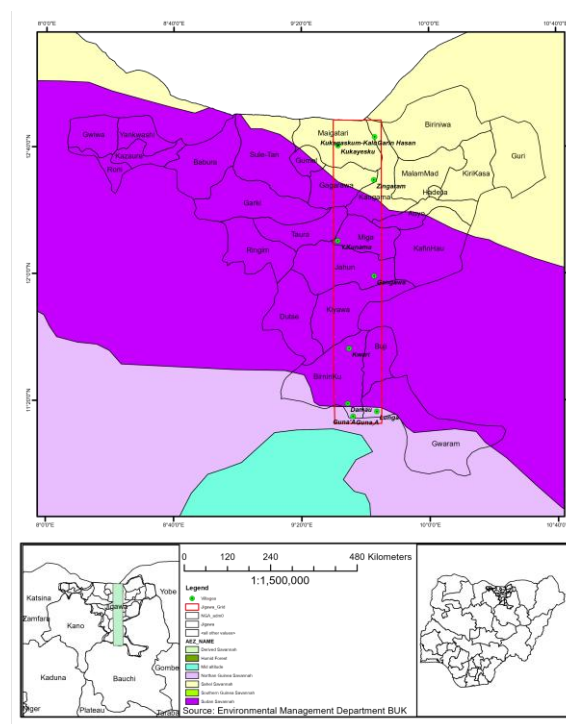


Figure 2 Jigawa State Agro-ecological Zone
Source: Environmental Management Department BUK, 2025

Sample Size Determination

The sample size for the quantitative component of the study was

determined using the Yamane (1967) formula at a 5% precision level. The projected population of Jigawa State was 7,499,100, based on the National Population Commission (NPC) population projection. This figure represents the state's projected total population and was used as the reference population to determine the minimum sample size.

$$n = \frac{N}{1 + N(e)^2}$$

The Yamane formula is expressed as:

Where:

n = required sample size

N = projected population of Jigawa State

e = level of precision (0.05)

Therefore, the calculated minimum sample size was approximately 400 respondents. The study consequently adopted a sample size of 400 households, with one eligible household head or primary food handler serving as the respondent in each selected household. The sample was then distributed across the selected study communities and agro-ecological environments to cover the Sahel, Sudan, and Northern Guinea Savannah settings represented in the study.

Instruments of Data Collection

Structured Questionnaire

A structured questionnaire was used to collect quantitative data. The questionnaire was administered to household respondents to collect quantitative data on socio-demographic characteristics, knowledge and perceptions of mold contamination, food storage and processing practices, preventive measures, and factors influencing mold contamination. The questionnaires were interviewer-administered in Hausa to minimize literacy barriers and ensure consistency.

Focus Group Discussions (FGDs)

FGDs explored community-level perceptions, traditional knowledge, storage challenges, and perceived health effects of consuming mold-contaminated food. Separate FGDs were held for male and female participants to encourage open discussion. Each group included 8–12 participants with substantial farming or food-handling experience.

Key Informant Interviews (KIs)

We conducted Key Informant Interviews (KIs) at the Local Government Area (LGA) and community levels within the selected study locations. The study purposively selected key informants based on their knowledge and direct involvement in agricultural production, post-harvest management, food safety, and community health. The informants included agricultural extension personnel, public health personnel, and village/community leaders from the selected LGAs and communities representing the study's agro-ecological zones. The interviews focused on local perceptions of mold contamination, common causes and contributing factors, storage and post-harvest practices, perceived health risks, and existing measures to prevent or manage mold contamination in agricultural commodities.

Observation Checklist

An observation checklist documented storage conditions, drying methods, housing ventilation, and visible signs of mold on stored commodities, complementing self-reported practices.

Data Collection Procedures and Quality Assurance

Trained research assistants fluent in Hausa and English supported field data collection. Training covered ethical conduct, informed consent, interview techniques, accurate translation, and data

recording.

Quality assurance measures included daily supervision, cross-checking completed questionnaires, debriefing sessions with field staff, and verifying data completeness and consistency. These procedures conform to best practices in community-based environmental health research.

Data Management and Analysis

Quantitative Data Analysis

Quantitative data were entered, cleaned, and analyzed using IBM SPSS Statistics (v25). Descriptive statistics (frequencies and percentages) summarized household perceptions, storage practices, and health risk awareness. Cross-tabulations and chi-square tests examined associations between socio-economic factors, perceptions, and storage practices.

Qualitative Data Analysis

Qualitative data from FGDs and KIs were transcribed and analyzed thematically. Codes were developed inductively and deductively based on study objectives. Emerging themes contextualized quantitative findings and explained observed behavioral patterns.

RESULTS AND DISCUSSION

Household Indicators Used to Identify Mold Contamination

Table 1 indicates that most households relied on sensory and visual indicators, particularly dark spots, discoloration, and odor, to identify mold contamination. Only a small proportion of respondents reported not knowing how to identify mold.

Table 1: Primary Indicators Used by Households to Identify Mold Contamination in Stored Food Commodities (N = 400)

Indicator used to identify mold	Frequency (n)	Percentage (%)
Dark spots on grains	312	78.0
Discoloration	284	71.0
Unpleasant smell/odor	256	64.0
Soft or powdery texture	198	49.5
Presence of insects	174	43.5
No knowledge of identification	46	11.5

Note: Multiple responses were permitted; therefore, percentages do not sum to 100%.

Source: Field Survey, 2025

Table 1 shows that most households identified mold contamination using visible and sensory cues, particularly dark spots (78.0%), discoloration (71.0%), and unpleasant odor (64.0%). Only 11.5% of respondents reported not knowing how to identify mold.

The heavy reliance on visible cues reflects low perceived susceptibility to invisible fungal toxins, especially mycotoxins such as aflatoxins, which are not always accompanied by obvious mold growth. Similar findings have been reported across Nigeria and West Africa, where mold is commonly perceived as a cosmetic or quality issue rather than a toxicological threat (Akanke et al., 2021; Awuah et al., 2023; Udomkun et al., 2020). Within the Health Belief Model (HBM), this perception limits motivation for preventive behaviors because households underestimate the likelihood of harm when mold is not visible (Bello et al., 2024; Day et al., 2025).

Household Perceptions of Factors Contributing to Mold Development

Most respondents correctly identified environmental and climatic factors such as rainfall, humidity, and moisture as major contributors to mold development. However, fewer households recognized modifiable human practices, including poor post-harvest handling and agronomic methods.

Table 2: Perceived Causes of Mold Contamination in Stored Agricultural Commodities

Perceived causal factor	Frequency (n)	Percentage (%)
High moisture during storage	326	81.5
Climatic conditions (heat/humidity)	304	76.0
Rainfall during harvest	298	74.5
Long storage duration	238	59.5
Poor post-harvest handling	212	53.0
Poor agronomic practices	164	41.0

Note: Multiple responses were permitted; therefore, percentages do not sum to 100%.

Source: Field Survey, 2025

Environmental and climatic factors, especially moisture (81.5%) and rainfall during harvest (74.5%), were most frequently identified as causes of mold development, while fewer respondents recognized poor agronomic practices (41.0%).

This pattern highlights a knowledge–practice gap, as respondents attribute mold contamination mainly to uncontrollable environmental forces rather than household-level behaviors. Under the Theory of Planned Behavior (TPB), this reflects weak attitude–behavior consistency and limited perceived behavioral control (Garba et al., 2022; Ouko et al., 2022). Similar findings have been documented in studies from Nigeria, Ghana, and Burkina Faso, where farmers acknowledge climate risks but underestimate their ability to reduce contamination through improved drying and storage (Udomkun et al., 2020; Sangaré et al., 2023).

Logistic Regression Predictors of Mold Contamination Risk

Insect infestation, extended storage duration, climatic stress, and traditional storage methods significantly increased the likelihood of mold contamination among households.

Table 3: Multivariate Logistic Regression Analysis of Factors Associated with Mold Contamination

Predictor Variable	Odds Ratio (OR)	95% CI	p-value
Insect infestation	2.31	1.58–3.39	<0.001*
Long storage duration (>6 months)	1.89	1.27–2.81	0.002*
Poor post-harvest handling	2.05	1.41–2.98	<0.001*
Climatic stress (high humidity)	1.74	1.18–2.56	0.006*
Traditional storage method	2.48	1.63–3.77	<0.001*

Model fit: Nagelkerke $R^2 = 0.43$; Hosmer–Lemeshow $p = 0.61$

Source: Field Survey, 2025

The strong association between insect infestation and mold contamination corroborates biological evidence that insect damage creates entry points for fungi and accelerates mycotoxin production (Mannaa et al., 2021; Suleiman et al., 2024). The persistence of traditional storage practices reflects structural and economic barriers, aligning with TPB's concept of limited perceived behavioral control. Studies across sub-Saharan Africa consistently report lower contamination levels among households using hermetic or improved storage technologies (Sangaré et al., 2023; Bello et al., 2024).

Awareness and Knowledge of Health Risks

While general awareness of mold contamination was relatively high, a substantial proportion of households demonstrated poor understanding of associated health risks, particularly long-term effects.

Table 4: Household Awareness of Health Implications of Mold and Mycotoxin Exposure

Knowledge category	Frequency (n)	Percentage (%)
Good knowledge	118	29.5
Fair knowledge	146	36.5
Poor knowledge	136	34.0
Total	400	100.0

Source: Field Survey, 2025

Although general awareness existed, only 29.5% of households demonstrated good knowledge of mold-related health risks. This gap explains the continued consumption of slightly moldy food reported in similar Nigerian studies. Within the HBM framework, low perceived severity reduces the urgency to discard contaminated food or invest in preventive measures (Asiedu et al., 2021; Akande et al., 2021). Recent evidence links chronic exposure to mycotoxins with impaired child growth, immune suppression, and increased cancer risk, underscoring the seriousness of the problem (WHO, 2023; Bello et al., 2024).

Socio-Economic Characteristics and Mold Knowledge

Education, income, gender, and household size were statistically associated with mold-related knowledge.

Table 5: Chi-Square Analysis of Socio-Economic Factors Associated with Mold Knowledge

Variable	χ^2 value	Df	p-value
Education level	18.42	2	<0.001*
Sex	6.87	1	0.009*
Age group	3.21	3	0.36
Income level	12.55	2	0.002*
Household size	7.94	2	0.019*

Source: Field Survey, 2025

These results confirm that mold contamination risk is socially patterned. Education and income enhance access to information and technologies, while gender differences reflect women's dominant role in food handling and storage. Similar socio-economic gradients have been reported in Nigeria, Kenya, and Ethiopia

(Adekunle et al., 2021; Ouko et al., 2022; Garba et al., 2022)

Effect of Knowledge on Mold Contamination Risk

Households with good knowledge of mold and mycotoxin risks were significantly less likely to experience mold contamination.

Table 6: Logistic Regression Showing Knowledge as a Protective Factor

Knowledge level	Odds Ratio (OR)	95% CI	p-value
Good knowledge	0.48	0.31–0.74	0.001*

Source: Field Survey, 2025

Households with good knowledge were 52% less likely to experience mold contamination. This finding empirically validates knowledge as a cue to action within the HBM. Increased awareness strengthens perceived severity and benefits, translating into safer storage behaviors. Comparable protective effects of knowledge have been documented across Nigeria and the Sahel, particularly where extension services are active (Suleiman et al., 2024; Day et al., 2025).

Focus Group Discussions (FGDs): Evidence from Study Findings

The Focus Group Discussions (FGDs) provided critical insights into community-level perceptions, traditional knowledge systems, storage challenges, and perceived health effects associated with mold-contaminated agricultural commodities. FGD findings corroborated the quantitative results, particularly the heavy reliance on visual and sensory indicators for mold identification and the limited understanding of invisible mycotoxin risks.

Across the FGDs, participants consistently described mold contamination using visible characteristics such as dark spots, discoloration, unpleasant odor, and powdery texture. This qualitative evidence supports the survey finding that 78.0% of households relied on dark spots and 71.0% on discoloration to identify mold contamination. A male farmer from the Sudan Savannah zone stated:

"If the grain has black or green spots and smells bad, we know it is spoiled. However, if it looks clean, we believe it is safe to eat." - (FGD participant, male farmer)



Plate 1. A Male Farmer Focus Group Discussion (FGD) on mold contamination from one of the selected villages in the Sahel savannah

Source: Field Survey, 2025

Similarly, female food handlers emphasized sensory judgment during food preparation:

"We remove the bad-looking ones and cook the rest. Once it is

cooked well, we believe it cannot harm us." - (FGD participant, female household food handler)



Plate 2. A Female household food handler Focus Group Discussion (FGD) on mold contamination from one of the selected villages in Sudan Savannah

Source: Field Survey, 2025

These perceptions explain the low proportion (29.5%) of households with good knowledge of health risks identified in the quantitative analysis and reflect a broader misconception that cooking or drying eliminates health risks. Similar beliefs have been reported in Nigeria and other sub-Saharan African settings, where mold is often viewed as a quality issue rather than a toxicological threat (Akande et al., 2021; Udomkun et al., 2020; Sani et al., 2023).

FGD discussions also revealed that environmental and climatic factors were perceived as the dominant causes of mold development, aligning with survey findings where moisture (81.5%) and rainfall during harvest (74.5%) were frequently cited. However, participants rarely acknowledged the role of modifiable post-harvest practices:

"Sometimes rain catches us during harvest; that is what causes the mold. It is not something farmers can control." - (FGD participant, mixed group)

This perception reflects limited perceived behavioral control, which helps explain the continued use of traditional storage methods despite their association with higher contamination risk, as demonstrated in the logistic regression results (OR = 2.48). Smallholder farmers in West Africa have similarly attributed mold contamination to uncontrollable environmental factors (Sangaré et al., 2023; Garba et al., 2022).

Regarding health effects, most participants associated moldy food with short-term illnesses such as stomach upset or diarrhea, while long-term effects were largely unknown:

"We know it can cause stomach pain, but we have never heard that it can cause serious sickness later." - (FGD participant, female group)

This finding reinforces the quantitative result that over one-third of households (34.0%) had poor knowledge of health risks and aligns with previous studies linking low risk perception to continued exposure to mycotoxins (WHO, 2023; Bello et al., 2024).

Key Informant Interviews (KIs): Evidence from Study Area

Key Informant Interviews (KIs) with agricultural extension workers, public health personnel, and community leaders provided expert perspectives that contextualized household behaviors and institutional gaps related to mold contamination. KIs confirmed that traditional storage practices, limited extension coverage, and low health risk awareness contribute significantly to household exposure, consistent with the study's quantitative predictors of

mold contamination.

An agricultural extension officer noted:

"Most farmers still store grains in woven bags without proper drying. Even when we advise them, cost and availability of improved storage are major challenges." - (KII, Agricultural Extension Officer)

This observation supports the logistic regression finding that poor post-harvest handling (OR = 2.05) and traditional storage methods significantly increased the risk of mold contamination. Similar constraints related to affordability and access to improved storage technologies have been widely reported in northern Nigeria (Bandyopadhyay et al., 2022; Bello et al., 2024).

Public health personnel emphasized the limited awareness of long-term health risks associated with mold and mycotoxin exposure:

"People come to the clinic with repeated illnesses, but they do not associate it with the food they eat. There is very little awareness about toxins from mold." - (KII, Community Health Worker)

Community leaders further highlighted socio-economic pressures that compel households to consume or sell mold-affected food:

"Because of poverty, people cannot afford to throw away food, even when they know it is not good." - (KII, Community Leader)

These qualitative insights reinforce the quantitative association between income, education, and mold knowledge, and explain why good knowledge emerged as a protective factor against contamination (OR = 0.48). They also align with regional evidence linking food insecurity and poverty to risky food consumption behaviors (Adekoya et al., 2022; Ouko et al., 2022).

Observation Checklist: Evidence from Study area

Field observations revealed that a substantial proportion of households stored cereals and legumes in woven polypropylene or jute sacks placed directly on floors or against walls with limited airflow. In many households, storage rooms were poorly ventilated, characterized by small or absent windows and high indoor temperatures, conditions known to favor fungal growth and mycotoxin production. These observations align with quantitative findings that identified traditional storage methods as a significant predictor of mold contamination (OR = 2.48, $p < 0.001$). Similar storage conditions have been widely reported in northern Nigeria and other semi-arid regions of sub-Saharan Africa (Udomkun et al., 2020; Bello et al., 2024).

Drying practices observed across communities were predominantly traditional, with grains sun-dried on bare ground, rooftops, or roadside surfaces. In several cases, commodities were dried inadequately before storage, particularly during periods of intermittent rainfall. This supports survey results indicating that 81.5% of households perceived moisture as a major cause of mold development and reinforces logistic regression findings showing that poor post-harvest handling significantly increased mold contamination risk (OR = 2.05, $p < 0.001$). Previous studies have demonstrated that inadequate drying and re-wetting during harvest significantly elevate fungal infestation and mycotoxin levels in stored grains (Bandyopadhyay et al., 2022; Ezekiel et al., 2021).

Several storage units showed visible signs of mold contamination, including discoloration, dark patches, powdery residues, and clumping of grains. These physical indicators corroborate the self-reported reliance on sensory cues for mold identification, as documented in the household survey where 78.0% of respondents cited dark spots as their primary indicator. However, the observation checklist also revealed instances where grains appeared visually clean but were stored under high-risk conditions, underscoring the limitation of visual assessment alone. This finding

supports qualitative evidence from FGDs indicating limited awareness of invisible mycotoxin contamination and is consistent with existing literature emphasizing that mycotoxins may be present even in the absence of visible mold (WHO, 2023; Akande et al., 2021).



Plate 3: Sorghum and Maize Panicles affected by mold infection, showing white or grayish aflatoxin growth, suggest contamination in the study area.

Source: Field Survey, 2025

In addition, insect infestation was frequently observed in storage facilities, particularly in households using non-hermetic storage methods. The presence of insects, damaged grains, and perforated sacks provides biological justification for the strong statistical association between insect infestation and mold contamination observed in the regression analysis (OR = 2.31, $p < 0.001$). Insects facilitate fungal colonization by increasing grain moisture and creating entry points for mold spores (Mannaa et al., 2021; Suleiman et al., 2024).

Overall, the observational findings independently verified household practices and environmental conditions that promote mold development. By triangulating observational data with quantitative and qualitative evidence, the study demonstrates that mold contamination in Jigawa State is not only a function of climatic exposure but also of modifiable household behaviors and structural storage limitations. Similar mixed-method approaches have been recommended in food safety and environmental health research to minimize reporting bias and improve the accuracy of exposure assessment (Creswell & Plano Clark, 2018; Molina-Azorin, 2016).

Conclusion

This study confirms that mold contamination of agricultural commodities is a widespread problem among households in Jigawa State, driven by unfavorable climatic conditions, reliance on traditional storage methods, and inadequate awareness of mycotoxin-related health risks. Although households commonly recognize visible mold, they markedly underestimate invisible contamination and long-term health effects, leading to continued consumption and circulation of contaminated foods. The findings reveal a pronounced knowledge–practice gap, with households

often attributing mold contamination to environmental factors rather than modifiable post-harvest behaviors. Socio-economic factors, particularly education and income, significantly shape household knowledge and practices, while improved awareness emerges as a key protective factor against contamination. Addressing mold contamination therefore requires integrated interventions that combine behavioral change, socio-economic support, and environmental management to achieve sustainable food safety improvements.

Recommendations

- i. Jigawa State Ministry of Agriculture should strengthen extension services by educating farmers and households on proper drying, sorting, handling, and storage of agricultural commodities to reduce mold contamination.
- ii. Jigawa State Ministry of Health should increase public health education on the potential health risks associated with consuming mold-contaminated agricultural commodities and encourage households to avoid visibly contaminated foods.
- iii. Local Government Authorities should support community-based awareness programmes on safe post-harvest handling and improved storage practices, particularly in rural farming communities.
- iv. Agricultural Extension Officers should provide practical training on appropriate storage technologies, adequate ventilation, moisture control, pest management, and regular inspection of stored commodities.
- v. Farmers and Household Food Handlers should improve post-harvest practices by properly drying commodities before storage, protecting stored foods from moisture and insects, and regularly inspecting stored products for visible signs of mold contamination.
- vi. Traditional and Community Leaders should support awareness campaigns and encourage households to adopt safer food handling and storage practices within their communities.
- vii. Universities and Research Institutions should conduct laboratory-based studies to identify the mold species present in agricultural commodities and determine the levels of associated mycotoxins. Such studies would complement the perception-based findings of the present study.
- viii. Jigawa State Government and Relevant Agricultural Agencies should promote access to affordable improved storage facilities and technologies that can reduce moisture accumulation, insect infestation, and fungal growth during storage.
- ix. Future Researchers should undertake longitudinal and laboratory-based studies across different agricultural commodities and agro-ecological zones of Jigawa State to provide further evidence on the occurrence, distribution, and health implications of mold contamination.

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