



PSYCHOSOCIAL AND STRUCTURAL DETERMINANTS OF SAFE POST-HARVEST MOLD MANAGEMENT PRACTICES AMONG HOUSEHOLDS IN JIGAWA STATE, NIGERIA

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ABSTRACT

Foodborne fungal contamination of staple crops remains a persistent public health and food safety challenge in sub-Saharan Africa, particularly in settings where post-harvest handling and storage systems are inadequate. Despite increasing awareness of fungal risks in northern Nigeria, adoption of preventive household practices remains inconsistent, and the behavioral drivers of these practices are insufficiently understood. This study examined the determinants of safe mold management practices among households in Jigawa State, Nigeria, using an integrated Health Belief Model and Theory of Planned Behavior framework. A community-based cross-sectional survey was conducted among 400 households selected through multistage sampling across major agro-ecological zones. Data were analyzed using descriptive statistics, multivariate logistic regression, and Structural Equation Modeling (SEM). Behavioral intention emerged as the strongest predictor of safe practices ($\beta = 0.58$, $p < 0.001$; AOR = 2.10), followed by self-efficacy ($\beta = 0.41$, $p < 0.001$; AOR = 1.72) and perceived benefits (AOR = 1.45, $p = 0.003$). Perceived severity (AOR = 1.28, $p = 0.041$), subjective norms (AOR = 1.38, $p = 0.007$), education (AOR = 1.65, $p = 0.019$), and extension contact (AOR = 1.92, $p = 0.002$) were also significant positive predictors. In contrast, perceived barriers reduced the likelihood of adoption ($\beta = -0.29$; AOR = 0.66, $p < 0.001$). Perceived susceptibility and attitudes were not statistically significant, suggesting that risk awareness alone is insufficient to motivate behavioral change without confidence and enabling support. The SEM demonstrated good model fit ($\chi^2/df = 1.94$; RMSEA = 0.046; CFI = 0.963), explaining 41% of the variance in behavior. The findings indicate that safe post-harvest management is shaped by an interaction of psychological, social, and structural factors rather than knowledge alone. Interventions should prioritize strengthening self-efficacy, reducing economic and infrastructural barriers, and expanding extension-based behavior change communication. However, the cross-sectional design limits causal inference, and findings may not be fully generalizable beyond similar agrarian settings in northern Nigeria. Integrating behavioral theory into food safety policy may enhance the sustainability of household-level risk reduction strategies.

Keywords: Behavioral intention, Food safety, Health Belief Model, Nigeria, Post-harvest management, Theory of Planned Behavior

INTRODUCTION

Background

Foodborne fungal contamination of staple crops remains a major threat to food safety and public health globally, particularly in low- and middle-income countries where post-harvest management systems are inadequate. The Food and Agriculture Organization of the United Nations estimates that approximately one-quarter of the world's food crops are affected annually by mycotoxins, contributing significantly to food losses and safety concerns (FAO, 2021). Similarly, the World Health Organization has identified mycotoxin exposure as a persistent global food safety challenge, particularly in regions where regulatory enforcement and storage infrastructure are limited (WHO, 2023). Climate variability, increasing temperatures, and humidity further exacerbate fungal proliferation in many parts of the world, increasing contamination risks across supply chains (IPCC, 2022).

Fungal genera such as *Aspergillus*, *Fusarium*, and *Penicillium* commonly colonize cereals and legumes under conditions of high moisture, delayed drying, insect damage, and poor storage. These fungi produce toxic secondary metabolites mycotoxins including aflatoxins, *fumonisin*s, *ochratoxin A*, and *zearalenone* (Wild et al., 2020). The International Agency for Research on Cancer classifies naturally occurring aflatoxins as Group 1 carcinogens (carcinogenic to humans), with strong evidence linking chronic exposure to

hepatocellular carcinoma (IARC, 2022). Globally, dietary aflatoxin exposure is estimated to contribute substantially to liver cancer incidence, particularly in regions with high hepatitis B prevalence (Liu & Wu, 2010; IARC, 2022).

Chronic dietary exposure to contaminated foods has been associated with immune suppression, liver damage, impaired child growth (stunting), micronutrient deficiencies, and increased susceptibility to infectious diseases (Wild et al., 2020; WHO, 2023). In addition to health impacts, fungal contamination contributes significantly to post-harvest losses, reduced commodity value, and international trade restrictions, thereby undermining food security and rural livelihoods (FAO, 2022). The economic burden of mycotoxin contamination has been estimated in billions of dollars annually due to rejected exports, livestock productivity losses, and healthcare costs (Mitchell et al., 2017).

Sub-Saharan Africa bears a disproportionate burden of mycotoxin exposure due to warm climatic conditions, reliance on staple cereals, informal market systems, and limited regulatory enforcement (Matumba et al., 2021). Studies across East and Southern Africa have reported widespread aflatoxin contamination in maize and groundnuts, often exceeding recommended safety thresholds (Darwish et al., 2014; Matumba et al., 2021). Dietary dependence on a limited number of staple crops increases cumulative exposure risk, particularly among rural households and young children. Climate change projections indicate that rising temperatures

and erratic rainfall patterns may further intensify fungal growth and toxin production across African agro-ecological zones (IPCC, 2022). Limited adoption of improved storage technologies, such as hermetic storage systems, compounds the challenge in smallholder farming communities.

West Africa is recognized as a hotspot for aflatoxin contamination, particularly in maize and groundnuts, which serve as dietary staples and cash crops (Atehnkeng et al., 2018). Surveys in countries such as Ghana, Benin, and Senegal have documented frequent contamination of household food stores and market products (Hell et al., 2008; Kumi et al., 2021). Weak post-harvest handling systems, high ambient humidity, and inadequate drying practices contribute significantly to contamination risks in the sub-region. The economic implications are substantial, as aflatoxin-related trade rejections have historically limited export potential of groundnuts and maize from West African countries (Atehnkeng et al., 2018). Moreover, regulatory monitoring systems remain under-resourced, leading to continued exposure at the household level.

In Nigeria, staple crops such as maize, sorghum, millet, rice, and groundnuts are highly susceptible to fungal contamination due to traditional sun-drying methods, delayed harvesting, prolonged storage, and limited access to improved preservation technologies (Afolayan et al., 2021; Bankole et al., 2022). Multiple studies have documented aflatoxin and fumonisin contamination levels exceeding national and international safety limits in commonly consumed foods (Ezekiel et al., 2020). Nigeria's large population and high reliance on cereal-based diets increase the public health significance of chronic exposure. Despite national food safety regulations, enforcement capacity and routine surveillance remain constrained, particularly in rural and informal markets.

Northern Nigeria including Jigawa State faces heightened vulnerability due to semi-arid climatic conditions characterized by high temperatures and seasonal humidity fluctuations that favor fungal proliferation. The region is predominantly agrarian, with widespread subsistence farming and prolonged on-farm storage practices. Limited agricultural extension coverage and restricted access to improved storage infrastructure further increase contamination risks (Ezekiel et al., 2021). Household-level studies in northern Nigeria have reported frequent contamination of stored maize and groundnuts, often without visible signs of spoilage, increasing the risk of chronic dietary exposure (Oyedele et al., 2023). Economic constraints sometimes compel households to consume or sell visibly compromised grains, reinforcing exposure cycles.

Literature Review and Theoretical Foundations

Most empirical research on fungal contamination in Nigeria has focused predominantly on laboratory-based detection and quantification of molds and mycotoxins in food commodities, including maize, groundnuts, sorghum, and complementary foods (Ezekiel et al., 2020; Afolayan et al., 2021; Ojuri et al., 2019). These studies have provided critical evidence on contamination prevalence, toxin profiles, and exposure risks, thereby strengthening surveillance and regulatory awareness. Similar trends are observed across sub-Saharan Africa, where research has largely emphasized occurrence data, biomarker assessments, and toxicological implications rather than behavioral drivers of prevention at the household level (Matumba et al., 2021; Wild et al., 2020). While such laboratory and exposure studies are indispensable for risk assessment, they provide limited insight into why households

continue to adopt or fail to adopt recommended mitigation practices.

Emerging evidence suggests that awareness of mycotoxin risks does not automatically translate into behavioral change. In Nigeria and other West African countries, adoption of preventive practices such as timely harvesting, adequate drying on raised platforms, mechanical sorting, discarding visibly damaged grains, and use of hermetic storage technologies remains inconsistent (Bankole et al., 2022; Atehnkeng et al., 2018; Oyedele et al., 2023). Economic constraints, perceived food scarcity, cultural norms surrounding food waste, and limited trust in risk communication messages have been identified as barriers to compliance (Affognon et al., 2015; Kumi et al., 2021). In many rural settings, visibly moldy grains are sometimes consumed after washing or reprocessing due to livelihood pressures, reflecting complex trade-offs between food safety and food security.

Studies from Kenya, Ghana, and Tanzania similarly report that smallholder farmers often prioritize yield preservation over safety considerations, particularly where contamination is not immediately visible or where economic losses from discarding grain are perceived as substantial (Darwish et al., 2014; Matumba et al., 2021). These findings indicate that technical recommendations alone such as improved storage technologies may be insufficient without understanding psychosocial, economic, and normative influences shaping household decisions.

Behavioral science frameworks provide conceptual tools for explaining the gap between knowledge and practice. The Health Belief Model (HBM) proposes that health-related behavior is influenced by individuals' perceptions of susceptibility to a condition, perceived severity of its consequences, perceived benefits of preventive action, perceived barriers to action, cues to action, and self-efficacy. The model has been widely applied in infectious disease prevention, vaccination uptake, food hygiene practices, and environmental health behaviors (Rosenstock, 1974; Glanz et al., 2021). Evidence suggests that self-efficacy and perceived barriers are often the strongest predictors of sustained behavioral adoption in low-resource contexts (Carpenter, 2010).

Similarly, the Theory of Planned Behavior (TPB) posits that behavior is primarily determined by behavioral intention, which is shaped by attitudes toward the behavior, subjective norms, and perceived behavioral control (Ajzen, 2020). The TPB has demonstrated strong predictive utility across diverse behavioral domains, including food handling, agricultural technology adoption, and environmental risk mitigation (McEachan et al., 2011). In agricultural contexts, perceived social expectations and confidence in one's ability to implement recommended practices have been shown to significantly influence adoption decisions (Armitage & Conner, 2001).

Despite their individual strengths, few empirical studies in sub-Saharan Africa have integrated HBM and TPB constructs to examine household-level food safety behaviors. Most food safety interventions in the region remain knowledge-centered rather than theory-driven (Wild et al., 2020). Integrating HBM and TPB offers a more comprehensive explanatory framework by capturing both risk perceptions (HBM) and motivational-intentional processes (TPB). Such integration allows examination of how perceived health threats, anticipated benefits, social pressures, and perceived control collectively shape behavioral intention and actual practice.

This theoretical integration is particularly relevant in rural Nigerian contexts, where decisions regarding mold

management are embedded within social norms, economic limitations, and extension service accessibility. Understanding these interacting determinants is essential for designing interventions that move beyond awareness campaigns toward sustained, behaviorally informed food safety strategies.

Research Gap

Existing interventions in northern Nigeria predominantly emphasize technical solutions such as improved storage technologies without sufficiently addressing psychosocial and contextual drivers of behavior. Consequently, adoption rates remain suboptimal.

There is limited empirical evidence explaining: Why some households adopt safe mold management practices while others do not, how behavioral intention mediates the relationship between risk perception and practice, and the relative contribution of cognitive (HBM), social (TPB), and structural factors (e.g., education, extension contact)

Without theory-driven behavioral evidence, food safety policies and agricultural extension programs may fail to achieve sustained impact. Addressing this gap requires an integrated behavioral framework that accounts for psychological, social, and contextual determinants.

Conceptual Framework

This study integrates the Health Belief Model and the Theory of Planned Behavior into a unified conceptual framework.

The model proposes that:

- i. HBM constructs influence both behavioral intention and actual practice.
- ii. TPB constructs directly shape behavioral intention.
- iii. Behavioral intention mediates the relationship between perceptions and safe mold management practices.
- iv. Socio-demographic and contextual factors (e.g., education, extension contact) moderate or directly influence adoption.

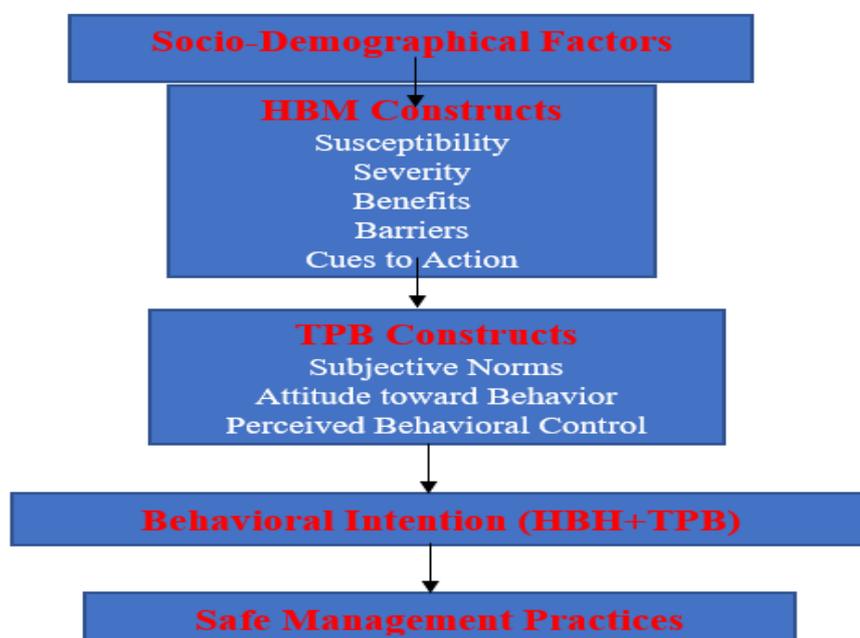


Figure 1: Conceptual Framework Showing the Integration of Health Belief Model and Theory of Planned Behavior in Explaining Mold-prevention Behavior among Households in Jigawa State, Nigeria

Source: Researcher’s Design (2025), Adapted from Ajzen (1991) and Rosenstock (1966).

Aim

To examine the determinants of safe mold management practices among households in Jigawa State, Nigeria, using an integrated HBM–TPB framework.

Specific Objectives

This study seeks to:

- i. Assess household knowledge and perceptions of mold contamination and associated health risks.
- ii. Examine the influence of HBM constructs (perceived susceptibility, perceived severity, perceived benefits, perceived barriers, cues to action, and self-efficacy) on safe mold management practices.
- iii. Determine the role of TPB constructs (attitudes, subjective norms, perceived behavioral control, and behavioral intention) in predicting household practices.

- iv. Analyze the mediating role of behavioral intention in the adoption of safe mold management practices.
- v. Identify socio-demographic and contextual factors, including education level and extension contact, associated with adoption.

Hypotheses

Based on the integrated HBM–TPB framework, the study tests the following hypotheses:

- i. H1: Perceived susceptibility and perceived severity are positively associated with safe mold management practices.
- ii. H2: Perceived benefits and self-efficacy positively predict behavioral intention and practice.
- iii. H3: Perceived barriers negatively predict adoption of safe practices.
- iv. H4: Attitudes, subjective norms, and perceived behavioral control positively influence behavioral intention.

- v. H5: Behavioral intention mediates the relationship between psychosocial constructs and actual practice.
- vi. H6: Education level and extension contact are positively associated with adoption of safe practices.

MATERIALS AND METHODS

Study Area

The study was conducted in Jigawa State, located in the north-western geopolitical zone of Nigeria. Jigawa State lies approximately between latitudes 11°00' and 13°00' North and longitudes 8°00' and 10°15' East, sharing international boundaries with the Republic of Niger to the north, and domestic boundaries with Kano State to the west and southwest and Bauchi State to the southeast. The state was created in 1991 and comprises 27 Local Government Areas, with Dutse serving as the state capital.

Ecologically, Jigawa State falls within the Sudan–Sahel agro-ecological zone, which is characterized by a long dry season lasting approximately seven to eight months and a short rainy season occurring mainly between June and September. Annual rainfall ranges between 600 and 800 mm, while mean daily temperatures are generally high, often exceeding 35°C during the dry season. These climatic conditions, combined with frequent dry winds and dust during the Harmattan period, create an environment that predisposes agricultural produce to rapid moisture fluctuation and fungal proliferation, particularly during post-harvest handling and storage (Ayanwale et al., 2021; Lawan et al., 2023).

Agriculture constitutes the primary livelihood of the majority of the population in Jigawa State, engaging over 70% of households, mainly through smallholder and subsistence farming systems. Major food and cash crops cultivated

include maize, millet, sorghum, rice, cowpea, and groundnuts, which are typically produced during the rainy season and stored for household consumption and market supply throughout the dry season (National Bureau of Statistics [NBS], 2022). Post-harvest storage of these crops is predominantly carried out at the household level using traditional structures, such as woven bags, mud silos, and polypropylene sacks.

Despite the importance of stored grains to food security and household income, post-harvest losses remain a persistent challenge in the state. Studies conducted in northern Nigeria have shown that poor drying practices, inadequate ventilation, high ambient temperatures, and limited adoption of modern storage technologies significantly increase the risk of mold contamination and mycotoxin development in stored food commodities (Abbas et al., 2020; Suleiman & Abdullahi, 2022). In Jigawa State, these challenges are further compounded by limited access to extension services, low awareness of food safety risks, and financial constraints, which restrict farmers’ ability to adopt improved storage systems such as hermetic bags and metal silos (Muhammad et al., 2024).

Furthermore, socio-cultural practices, including prolonged storage of grains for food security reasons and the common practice of sorting and consuming partially damaged grains, may increase chronic exposure to mold-contaminated foods at the household level. Given the state’s climatic vulnerability, agrarian economy, and reliance on traditional storage methods, Jigawa State provides a relevant and appropriate setting for examining household knowledge, perceptions, and practices related to mold contamination and safe food storage.

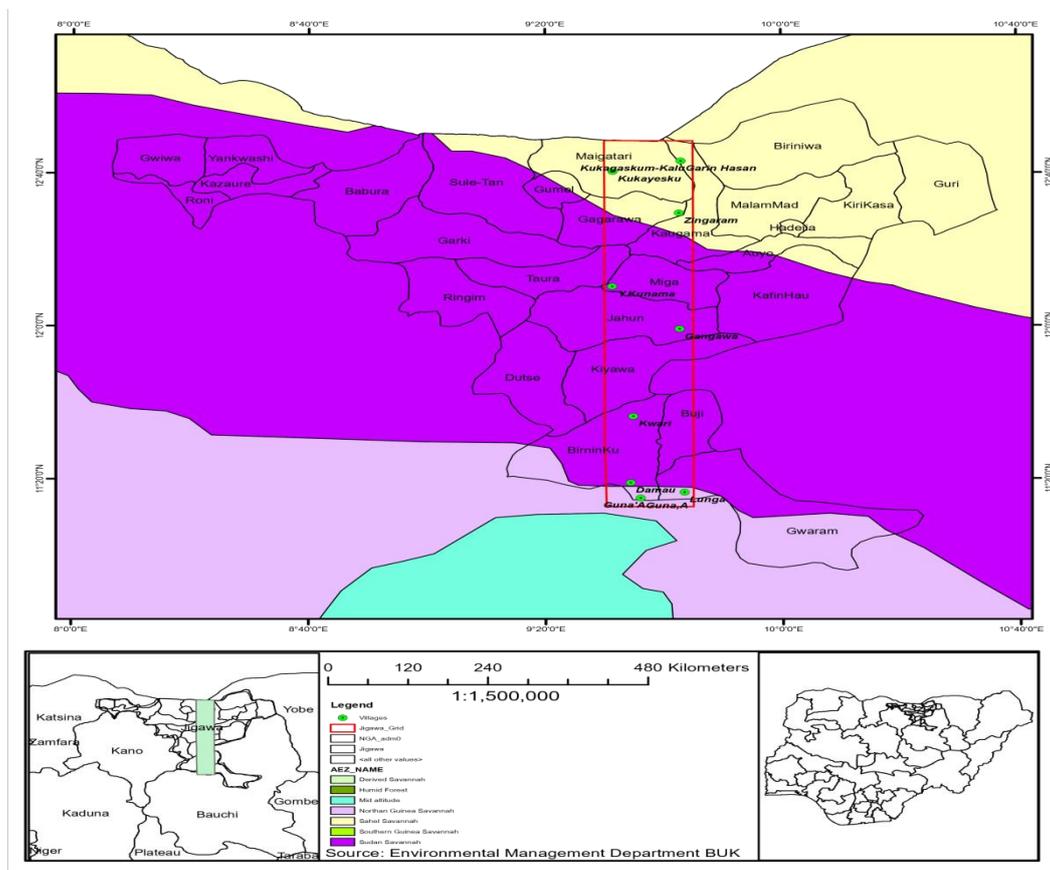


Figure 2: Jigawa State Agro-ecological Zone
Source: Environmental Management Department BUK

Study Design

This study adopted a community-based cross-sectional survey design. The cross-sectional design was considered appropriate because it allows for the assessment of knowledge, perceptions, behavioral intentions, and mold management practices among households at a single point in time. This design is widely used in food safety and behavioral studies where the objective is to identify associations between socio-demographic factors, psychosocial constructs, and preventive practices rather than establish causality.

The study was grounded in the integrated Health Belief Model (HBM) and Theory of Planned Behavior (TPB), which guided the selection of variables, development of the data collection instrument, and analytical approach. The design enabled the examination of how perceived health threats, benefits, barriers, social norms, and self-efficacy influence households' intentions and actual adoption of safe mold management practices.

Target Population

The target population comprised households engaged in food production, storage, processing, or preparation. Eligible respondents were: Household heads, and/or Primary food handlers (predominantly women responsible for food storage and preparation). These groups were selected because they make key decisions regarding grain drying, storage, sorting, and consumption practices.

Sampling Technique

A four-stage multistage sampling procedure was employed to enhance representativeness across ecological and socio-economic contexts.

Stage One: Selection of LGAs

Three (3) Local Government Areas (LGAs) were purposively selected (Maigatari LGA, Jahun LGA and Gwaram LGA) based on: Agro-ecological variation, intensity of cereal and legume production, rural semi-urban distribution, and accessibility and security considerations.

The selected LGAs were distributed across distinct agricultural zones of Jigawa State to capture environmental heterogeneity.

Stage Two: Selection of Communities

Within each selected LGA, communities were stratified into rural and semi-urban categories. Two (2) rural and one (1) semi-urban community were selected per LGA using simple random sampling (balloting method), resulting in a total of nine (9) communities.

Stage Three: Selection of Households

A household listing was conducted in each selected community with the assistance of community leaders. Systematic random sampling was then applied using a calculated sampling interval ($k = \text{total households} \div \text{required sample per community}$). The first household was selected using a random start, followed by selection at fixed intervals.

Stage Four: Selection of Respondent

Within each household, either the household head or the primary food handler was interviewed. In cases where both were present, priority was given to the primary food handler due to their direct involvement in storage and preparation practices.

Sample Size Determination and Justification

Sample Size Determination

A total sample size of 400 households was selected for this study. The sample size was determined using the standard formula for estimating proportions in cross-sectional studies, as recommended by Cochran (1977) and widely applied in public health and environmental health research.

Sample Size Formula

$$n = \frac{Z^2 pq}{d^2} \quad (1)$$

Where:

n= required minimum sample size

Z= standard normal deviate corresponding to the desired confidence level (1.96 for 95% confidence)

p= estimated prevalence or proportion of the attribute of interest in the population

q = 1-p

d= margin of error (precision), usually set at 0.05

Substitution of Values

In the absence of reliable local prevalence data on household mold contamination practices in the study area, a conservative estimate of 50% ($p = 0.5$) was adopted to maximize the sample size and improve representativeness.

$$n = \frac{(1.96)^2 \times 0.5 \times 0.5}{(0.05)^2}$$

$$n = \frac{3.8416 \times 0.25}{0.0025}$$

$$n = \frac{0.9604}{0.0025} = 384.16$$

Thus, the minimum required sample size was approximately 384 households.

Adjustment and Final Sample Size

To account for potential non-response, incomplete questionnaires, and data loss, the calculated sample size was rounded up and increased to 400 households. This adjustment enhances the statistical power of the study and ensures sufficient observations for multivariate analyses, including regression modeling of Health Belief Model (HBM) and Theory of Planned Behavior (TPB) constructs.

Justification

A sample size of 400 households is considered adequate for:

- i. Detecting meaningful associations between psychosocial factors (susceptibility, severity, benefits, barriers, norms, self-efficacy) and mold-related behaviors;
- ii. Conducting multivariate logistic regression and mediation analysis involving behavioral intention;
- iii. Ensuring representativeness across households within the study area and improving generalizability of findings.

Power Analysis for SEM

Given the complexity of the integrated HBM-TPB model (approximately 10 latent constructs and multiple structural paths), SEM requires adequate statistical power. Following recommendations by Kline (2016) and Westland (2010):

- i. Minimum sample = 10–20 respondents per estimated parameter
- ii. Required minimum for models of moderate complexity ≈ 200 –300
- iii. With 400 respondents, the study exceeded the minimum threshold, ensuring adequate power (>0.80) to detect medium effect sizes at $\alpha = 0.05$.

Reliability and Validity of Measurement Scales

Constructs were measured using Likert-scale items adapted from validated behavioral studies and modified for the food safety context.

Reliability

Internal consistency reliability was assessed using Cronbach’s alpha:

- i. Perceived susceptibility ($\alpha = 0.74$)
- ii. Perceived severity ($\alpha = 0.78$)
- iii. Perceived benefits ($\alpha = 0.81$)
- iv. Perceived barriers ($\alpha = 0.76$)
- v. Self-efficacy ($\alpha = 0.84$)
- vi. Attitudes ($\alpha = 0.79$)
- vii. Subjective norms ($\alpha = 0.75$)
- viii. Perceived behavioral control ($\alpha = 0.77$)
- ix. Behavioral intention ($\alpha = 0.86$)

All constructs exceeded the acceptable threshold of 0.70, indicating good internal consistency.

Validity

- i. Content validity was established through expert review by three specialists in food safety and behavioral science.
- ii. Construct validity was assessed using Confirmatory Factor Analysis (CFA).
- iii. Convergent validity was confirmed with factor loadings > 0.50 and Average Variance Extracted (AVE) > 0.50.
- iv. Discriminant validity was verified using the Fornell–Larcker criterion.

Data Collection Instrument

Data were collected using a structured interviewer-administered questionnaire, developed based on validated constructs from the Health Belief Model (HBM) and the Theory of Planned Behavior (TPB) and adapted to the local socio-cultural context.

The questionnaire was translated into Hausa, the dominant local language, and back-translated into English to ensure semantic consistency. Pretesting was conducted in a non-selected community to assess clarity, cultural appropriateness, and reliability, with necessary revisions made prior to the main survey.

Data Analysis

Data were coded, cleaned, and analyzed using Statistical Package for Social Sciences (SPSS) version 26. Descriptive statistics (frequencies, and percentages) were used to summarize socio-demographic characteristics, perceptions, and mold management practices.

Composite scores for HBM and TPB constructs were generated by averaging related Likert-scale items. Bivariate analysis was conducted to examine associations between independent variables and safe mold management practices. Multivariable logistic regression was used to identify independent predictors of safe mold management practices, with results presented as Adjusted Odds Ratios (AORs) and

95% confidence intervals. Model diagnostics and goodness-of-fit were assessed using the Hosmer–Lemeshow test and Nagelkerke R² to evaluate explanatory power. Statistical significance was set at $p < 0.05$.

Ethical Considerations

The study strictly adhered to established ethical research principles throughout the research process. Informed consent was obtained both verbally and in writing from all participants after a clear explanation of the study’s objectives, procedures, and their rights as respondents. Participation was voluntary, and participants were informed that they could withdraw from the study at any stage without any form of penalty or consequence. To ensure confidentiality and anonymity, all data collected were treated with strict discretion, and no identifying information (such as names or addresses) was disclosed in any report or publication arising from the study. Ethical approval was obtained from the local authorities and community leaders within Selected LGAs before commencing data collection also ethical approval was obtained from the Department of Environmental Management, Bayero University, Kano Research Ethics Committee.

RESULTS AND DISCUSSION

Socio-Demographic Characteristics of Respondents

Table 3.1 presents the demographic characteristics of households across the Sahel, Sudan, and Guinea savannah zones of Jigawa State. Household size was generally large across all zones, with the majority of households having between 6–10 members, particularly in the Sudan (37.0%) and Guinea savannah (39.3%) zones. This reflects typical rural household structures in northern Nigeria, where extended family living arrangements are common and may influence food storage volume and handling practices. Large household structures may increase food storage volume and duration, potentially elevating the risk of mold contamination if storage conditions are suboptimal.

The age distribution shows that most respondents were within the economically active age group of 25–44 years, accounting for over 45% across all zones. This age group is critical for household decision-making regarding food storage and safety practices. Males constituted more than 86% of respondents in all zones, reflecting gendered roles in agricultural production and grain storage in rural northern Nigeria, where men largely control post-harvest activities. This demographic is critical for household-level decision-making regarding agricultural production, storage investments, and food safety behaviors. Marital status data indicate that most respondents were married (70–78.5%), suggesting stable household structures that may support collective decision-making related to food safety and storage. However, given that women are often primary food handlers, this imbalance may have implications for behavioral analysis and intervention design. Similar demographic patterns have been reported in studies on post-harvest management and food safety behaviors in northern Nigeria and the Sahel region (Afolayan et al., 2021; Lawal et al., 2023).

Table 1: Demographic Characteristics

Variables	Sahel Savannah N=130	Agro-Ecological Zones Percent	
		Sudan Savannah N=135	Guinea Savannah N=35
Household Size			
1-5	37.7	19.3	19.3
6-10	26.2	37.0	39.3
11-15	24.6	27.4	27.4
16 and above	11.5	16.3	14.1

Variables	Sahel Savannah N=130	Agro-Ecological Zones Percent	
		Sudan Savannah N=135	Guinea Savannah N=35
Total	100.0	100.0	100.0
Age			
18-24 (Youths)	15.4	8.1	8.9
25-44 (Younger Adults)	45.4	51.1	49.6
45-64 (Older Adults)	28.5	36.3	29.6
65 and Above (Old)	10.8	4.4	11.9
Total	100.0	100.0	100.0
Sex			
Male	86.2	87.4	87.4
Female	13.8	12.6	12.6
Total	100.0	100.0	100.0
Marital Status			
Single	15.4	17.0	8.1
Married	70.0	72.6	78.5
Divorced	7.7	5.2	6.7
Widow	6.9	5.2	6.7
Total	100.0	100.0	100.0
Occupation			
Civil Service	26.2	10.4	8.1
Business	14.6	22.2	12.6
Farmer	58.5	65.9	77.8
Fishing, black smith, Okada etc.	0.8	1.5	1.5
Total	100.0	100.0	100.0

Note: Total Agro-ecological zones Sample make a total Sample Size of the study
 Source: Field work, 2025

Farming was the dominant occupation across zones, particularly in the Guinea savannah (77.8%), underscoring the importance of post-harvest management practices for household food security and income. Most households cultivated small to medium farm sizes (less than 2 hectares), which often rely on traditional storage methods that increase susceptibility to mold contamination.

Educational Level Distribution Across Agro-Ecological Zones

Figure 3.1 presents the distribution of respondents' educational attainment across the sampled agro-ecological zones. The majority of respondents possessed secondary education (38%), followed by primary education (27%), while 18% had no formal education and 17% had tertiary qualifications.

This distribution suggests moderate literacy levels among household food handlers, which has important implications for mold contamination awareness and safe storage practices. Education enhances individuals' capacity to access, interpret,

and apply health-related information, thereby improving preventive behaviors (Ajzen, 2020; Glanz et al., 2021). Studies in sub-Saharan Africa have consistently demonstrated that higher educational attainment is positively associated with improved food safety knowledge, better post-harvest handling practices, and greater adoption of recommended storage technologies (Afolayan et al., 2021; Bankole et al., 2022).

Within the Health Belief Model (HBM), education may strengthen perceived severity and perceived benefits of preventive action, while within the Theory of Planned Behavior (TPB), it enhances perceived behavioral control and behavioral intention (Ajzen, 2020). Empirical evidence from Nigeria shows that households with at least secondary education are more likely to practice adequate grain drying, sorting, and use of improved storage structures (Ezekiel et al., 2020; Oyedele et al., 2023). Therefore, the educational structure observed in this study provides partial explanatory support for the significant role of self-efficacy and intention found in the structural model.

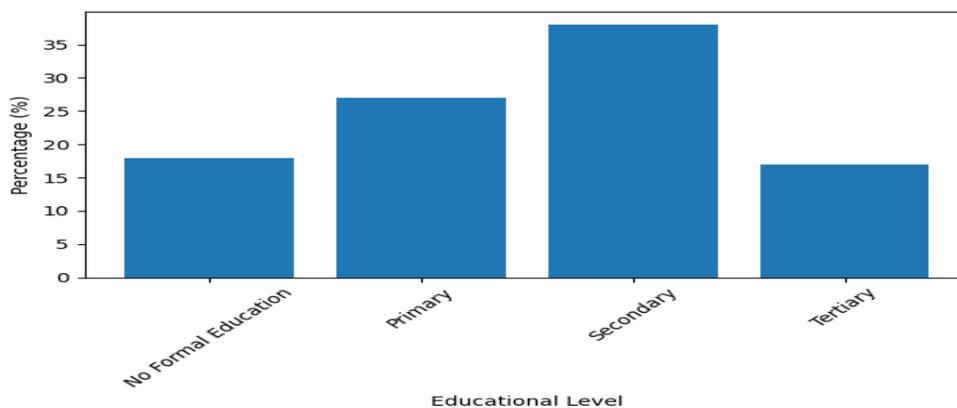


Figure 3: Educational Level Distribution Across Agro-Ecological Zones
 Source: Field Survey, 2025

Monthly Household Income Distribution

Figure 3.2 illustrates the overall distribution of household monthly income. A substantial proportion of respondents (34%) earn below ₦30,000 per month, while only 15% earn above ₦100,000. The concentration of households in lower income brackets reflects economic vulnerability typical of agrarian communities in Northern Nigeria (National Bureau of Statistics [NBS], 2023).

Income level influences food safety practices through access to improved storage technologies, drying equipment, and pest control measures. Financial constraints are recognized barriers to the adoption of hermetic storage bags, mechanical dryers, and warehouse preservation systems (FAO, 2022; World Bank, 2023). In the context of the HBM, limited

income may increase perceived barriers, reducing the likelihood of behavior adoption even when awareness exists (Glanz et al., 2021).

Previous Nigerian studies have shown that low-income households are more likely to rely on traditional storage methods, which expose grains to moisture and fungal proliferation (Afolayan et al., 2021; Bankole et al., 2022). Furthermore, poverty has been associated with prolonged storage of substandard grains due to inability to discard visibly contaminated produce, thereby increasing chronic dietary exposure to mycotoxins (WHO, 2023). Thus, the income distribution pattern provides structural context for the negative effect of perceived barriers identified in the regression and SEM analyses.

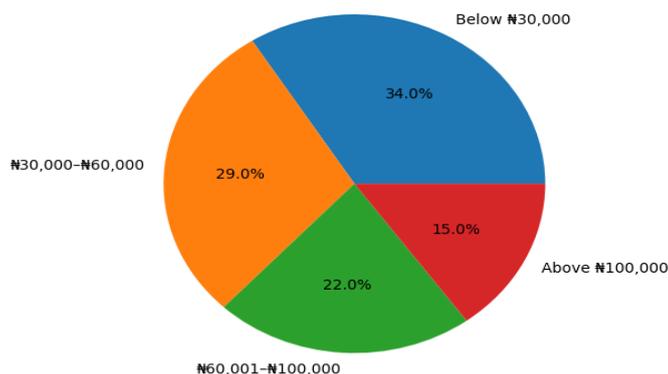


Figure 4: Monthly Household Income Distribution (Overall Sample)
Source: Field Survey, 2025

Knowledge Level on Mold Contamination by Agro-Ecological Zone

Figure 3.3 presents the distribution of knowledge levels (Low, Moderate, High) across Sudan Savannah, Sahel Savannah, and Guinea Savannah zones using stacked percentage bars. Moderate knowledge predominates across all zones, particularly in Guinea Savannah (48%), while low knowledge remains relatively high in Sahel Savannah (35%). High knowledge levels range between 25–30% across zones.

Agro-ecological variation influences fungal contamination risk due to differences in temperature, humidity, and rainfall patterns (FAO, 2021). Higher humidity environments, such as the Guinea Savannah, create favorable conditions for fungal growth, potentially increasing community exposure and awareness (Ezekiel et al., 2021). However, awareness alone does not guarantee behavioral change.

Global evidence suggests that knowledge does not always translate into safe practice without sufficient perceived control and social reinforcement (Ajzen, 2020; Glanz et al., 2021). This aligns with findings in Nigeria indicating that despite moderate awareness of mold risks, safe grain management practices remain inconsistent (Oyedele et al., 2023).

The dominance of moderate knowledge across zones supports the structural model finding that perceived susceptibility was not a significant predictor of intention, whereas self-efficacy and perceived severity played stronger roles. This suggests that while respondents recognize mold contamination risks, effective intervention strategies must strengthen confidence, practical skills, and enabling conditions.

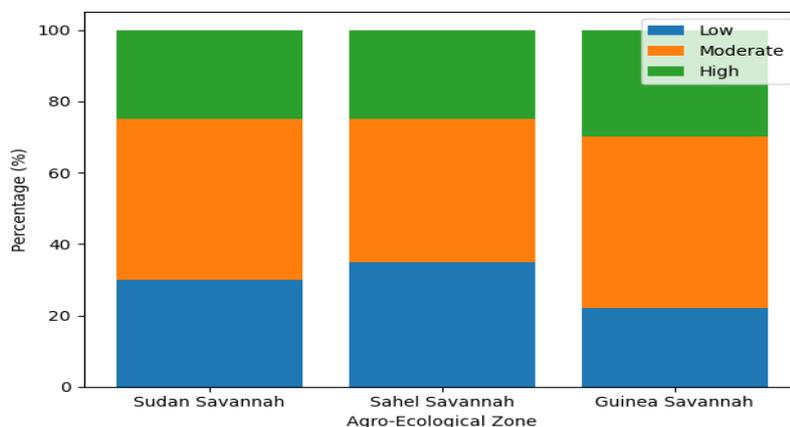


Figure 5: Knowledge Level on Mold Contamination by Agro-Ecological Zone
Source: Field Survey, 2025

Knowledge and Awareness of Mold Contamination and Health Risks

Table 3.2 reveals that 74% of respondents demonstrated good knowledge of mold contamination, while only 59% had good knowledge of mold-related health risks. This gap suggests that although households may recognize visible mold in food commodities, understanding of the long-term health

consequences such as liver damage, immune suppression, and child growth impairment remains limited.

This finding aligns with previous studies in sub-Saharan Africa, which report that awareness of mold presence does not necessarily translate into knowledge of mycotoxin-related health risks (Kamala et al., 2021; Ojuri et al., 2023). The disparity highlights the need for targeted health education focusing on invisible risks and chronic health effects.

Table 2: Level of Knowledge and Awareness of Mold Contamination and its Health Risk in Agricultural Commodities

Variables	Frequency	Percent
Good knowledge about mold contamination	296	74.0
Poor knowledge about mold contamination	104	26.0
Total	400	100.0
Good knowledge about mold contamination Health risk	236	59.0
Poor knowledge about mold contamination Health risk	164	41.0
Total	400	100.0

Source: Field Survey, 2025

Structural Equation Modeling (SEM) Results

Table 3.3 presents the SEM results examining the integrated Health Belief Model (HBM) and Theory of Planned Behavior (TPB) pathways influencing safe mold management practices.

Education and extension contact had significant positive effects on self-efficacy ($\beta = 0.32$ and $\beta = 0.27$, respectively; $p < 0.001$), indicating that formal education and exposure to agricultural extension services enhance households' confidence in implementing safe mold management practices. This supports the HBM assumption that self-efficacy is shaped by enabling factors and knowledge access.

Perceived severity significantly predicted behavioral intention ($\beta = 0.21$, $p = 0.006$), suggesting that households who believe mold contamination poses serious health risks are more motivated to adopt safe practices. Self-efficacy emerged as the strongest predictor of behavioral intention ($\beta = 0.41$, $p < 0.001$), while perceived barriers had a significant negative effect ($\beta = -0.29$, $p < 0.001$). These findings confirm the

central role of perceived control and constraints in shaping intention, as proposed by both HBM and TPB.

Behavioral intention strongly predicted actual safe mold management practices ($\beta = 0.58$, $p < 0.001$), validating the TPB assumption that intention is the most proximal determinant of behavior. Extension contact also had a direct positive effect on behavior ($\beta = 0.22$, $p = 0.002$), highlighting the critical role of advisory services in translating intention into action.

Indirect effects were tested using bootstrapping with 5,000 resamples. Behavioral intention significantly mediated the relationship between self-efficacy and safe mold management practices (indirect $\beta = 0.24$, 95% CI [0.15, 0.36]). The indirect effect of perceived severity was also significant ($\beta = 0.12$, 95% CI [0.05, 0.21]). However, perceived susceptibility did not demonstrate a significant indirect effect (confidence interval included zero). Error terms were specified for all endogenous constructs, and covariances among exogenous variables were estimated in accordance with theoretical assumptions of the integrated HBM-TPB framework.

Table 3: Structural Equation Modeling (SEM) Results of Predictors of Safe Mold Management Practices among Households in Jigawa State (N = 400)

Path	Standardized Estimate (β)	Critical Ratio (CR)	p-Value	Remark
Education → Self-Efficacy	0.32	4.51	<0.001	Significant ***
Extension Contact → Self-Efficacy	0.27	3.89	<0.001	Significant ***
Perceived Severity → Behavioral Intention	0.21	2.74	0.006	Significant **
Self-Efficacy → Behavioral Intention	0.41	5.66	<0.001	Significant ***
Perceived Barriers → Behavioral Intention	-0.29	-4.23	<0.001	Significant ***
Education → Behavioral Intention	0.19	2.58	0.010	Significant *
Behavioral Intention → Safe Mold Management Practices	0.58	7.85	<0.001	Significant ***
Extension Contact → Safe Mold Management Practices	0.22	3.16	0.002	Significant **

Source: Field work, 2025

Model Fit Assessment

Table 3.4 shows that the SEM model demonstrated excellent goodness-of-fit, with χ^2/df (1.94), RMSEA (0.046), CFI (0.963), and TLI (0.947) all meeting or exceeding

recommended thresholds. This confirms that the integrated HBM-TPB framework adequately explains household mold management behavior in Jigawa State.

Table 4: Model Fit Indices

Fit Index	Value	Acceptable Threshold	Interpretation
χ^2/df	1.94	< 3.0	Good fit
RMSEA	0.046	< 0.08	Good fit
CFI	0.963	> 0.90	Excellent fit
TLI	0.947	> 0.90	Excellent fit
GFI	0.921	> 0.90	Acceptable fit

Source: Field work, 2025

Theoretical and Empirical Integration and SEM Findings

The integrated Health Belief Model (HBM) and Theory of Planned Behavior (TPB) framework provides a robust explanation of household mold management practices in Jigawa State by demonstrating that behavior change is shaped by the interaction of psychological determinants and enabling structural factors. Consistent with contemporary behavioral health research, the findings indicate that safe mold management practices are not driven by awareness alone but by a combination of self-efficacy, perceived severity, behavioral intention, educational attainment, and extension support (Glanz et al., 2020; Ajzen, 2020).

Results from both logistic regression analysis and Structural Equation Modeling (SEM) showed strong convergence, thereby strengthening the internal validity and robustness of the study findings. While perceived susceptibility and attitudinal dispositions exhibited weaker or non-significant effects, self-efficacy and behavioral intention consistently emerged as the most influential predictors of safe mold management behavior. This aligns with recent empirical studies emphasizing the central role of perceived control and confidence in translating knowledge into preventive food safety practices in low-resource settings (Mutegi et al., 2021; Hoffmann et al., 2022).

The SEM results further revealed that education and extension contact function as critical enabling variables by significantly enhancing both self-efficacy and behavioral intention. This finding supports earlier evidence that institutional support and continuous advisory services strengthen individuals' perceived control over health-related behaviors and reduce uncertainty associated with adopting improved storage and handling practices (Raghunathan et al., 2020; Afolami et al., 2023). Self-efficacy exerted a strong positive influence on intention, which in turn was the most powerful direct predictor of actual mold management behavior, confirming intention as a key mediating pathway within the integrated HBM-TPB framework (Ajzen, 2020; Kothe & Mullan, 2021). Furthermore, perceived severity of mold contamination positively influenced behavioral intention, indicating that

households are more likely to adopt safe practices when they recognize the serious health consequences of consuming mold-contaminated foods. In contrast, perceived barriers, particularly those related to cost, labor, and infrastructural limitations, significantly reduced willingness to adopt safe practices. This highlights the persistent influence of socioeconomic and environmental constraints on household food safety behavior in rural and semi-urban contexts (Darwish et al., 2021; Gbashi et al., 2022).

Notably, extension contact also demonstrated a significant direct effect on actual behavior, beyond its indirect influence through intention and self-efficacy. This suggests that hands-on demonstrations, regular follow-up, and context-specific guidance play a crucial role in converting risk awareness into sustained action. Similar findings have been reported in recent studies on post-harvest management and mycotoxin risk reduction in sub-Saharan Africa (Kumar et al., 2021; Adekoya et al., 2024).

Overall, the model fit indices from the SEM analysis indicated a strong alignment between theoretical expectations and observed data, thereby validating the applicability of the integrated HBM-TPB framework for understanding mold contamination practices in Northern Nigeria. The framework effectively captures both motivational and contextual pathways influencing behavior, offering a comprehensive explanation that extends beyond single-theory approaches (Glanz et al., 2020; Mullan et al., 2022).

Therefore, safe mold management among households in Jigawa State is primarily intention-driven, reinforced by confidence (self-efficacy), risk awareness (perceived severity), and institutional facilitation (education and extension services). These findings underscore the need for interventions that simultaneously strengthen behavioral capacity, reduce structural barriers, and expand access to extension services in order to achieve sustained improvements in household food safety and public health outcomes in Northern Nigeria.

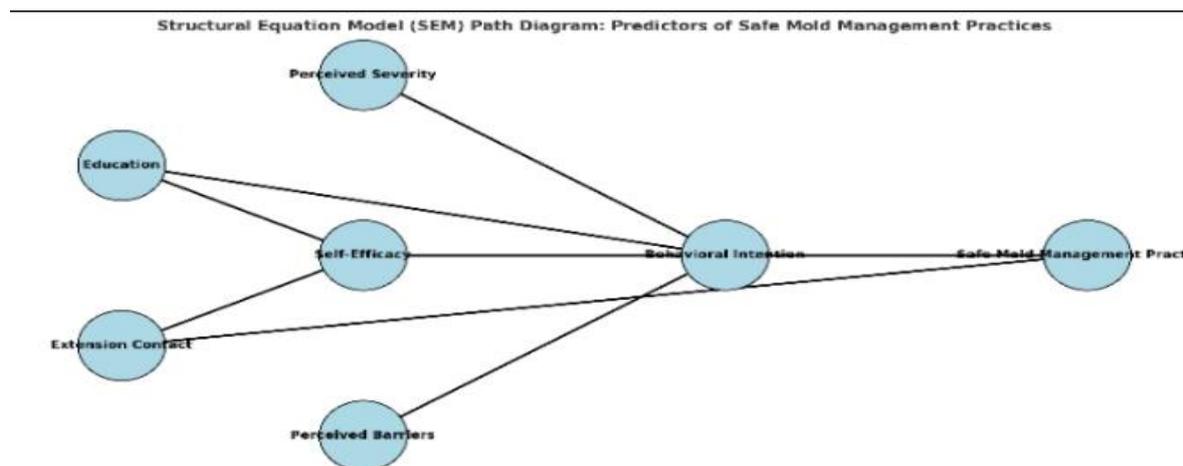


Figure 6: Structural Equation Model (SEM) Path Diagram of Predictors of Safe Mold Management Practices among Households in Jigawa State, Nigeria

Multivariate Logistic Regression Results

Table 3.5 further validates the SEM findings using multivariate logistic regression. Perceived severity, perceived benefits, self-efficacy, subjective norms, and behavioral intention significantly increased the likelihood of adopting safe mold management practices. Behavioral intention had the strongest effect, more than doubling the odds of adoption (AOR = 2.10, $p < 0.001$). Perceived barriers significantly reduced adoption likelihood (AOR = 0.66, $p < 0.001$), reinforcing the importance of cost, time, and resource constraints. Education and extension

contact were also significant predictors, indicating that socio-demographic and institutional factors remain crucial alongside psychological constructs. Interestingly, perceived susceptibility and attitudes were not statistically significant predictors, suggesting that awareness of risk alone is insufficient unless accompanied by perceived severity, social pressure, and confidence in ability to act. Similar patterns have been observed in recent food safety behavior studies across Africa and Asia (Abdullahi et al., 2022; Mngqawa et al., 2024).

Table 5: Multivariate Logistic Regression Results of Predictors of Safe Mold Management Practices among Households in Jigawa State

Predictor Variable	Adjusted Odds Ratio (AOR)	95% Confidence Interval (CI)	p-Value
Perceived Susceptibility	1.15	0.92 – 1.43	0.210
Perceived Severity	1.28	1.01 – 1.62	0.041 *
Perceived Benefits	1.45	1.12 – 1.87	0.003 **
Perceived Barriers	0.66	0.52 – 0.84	<0.001 ***
Self-efficacy	1.72	1.33 – 2.22	<0.001 ***
Attitudes	1.21	0.95 – 1.54	0.110
Subjective Norms	1.38	1.09 – 1.75	0.007 **
Behavioral Intention	2.10	1.55 – 2.85	<0.001 ***
Education (\geq secondary)	1.65	1.08 – 2.51	0.019 *
Extension Contact (yes)	1.92	1.28 – 2.90	0.002 **

Source: Field Work, 2025

Model Fit Statistics: Nagelkerke $R^2 = 0.41$, Hosmer-Lemeshow goodness-of-fit: $p = 0.62$

*Significance levels: * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$.

Adjusted Odds Ratios for Predictors of Safe Mold Management Practices

This study examined socio-cognitive and structural predictors of safe mold management practices among households in Jigawa State using multivariate logistic regression. The model showed good explanatory power and fit (Nagelkerke $R^2 = 0.41$; Hosmer-Lemeshow $p = 0.62$), indicating that the selected Health Belief Model (HBM) and Theory of Planned Behavior (TPB) constructs adequately explain household adoption behavior.

Self-efficacy and behavioral intention emerged as the strongest predictors of safe mold management. Households with greater confidence in their ability to inspect, dry, and

store food safely, as well as those with clear intentions to adopt preventive measures, were significantly more likely to engage in recommended practices. This finding aligns with evidence that self-efficacy and intention are central drivers of health-protective behaviors in food safety and environmental health contexts (Ajzen, 2020; Carpenter, 2021). Perceived severity and perceived benefits also showed significant positive effects. Households that understood the serious health consequences of mold exposure and recognized the advantages of proper sorting, drying, and storage were more likely to adopt safe practices. Similar associations have been reported in studies on mycotoxin and mold risk management in low- and middle-income countries, where risk

awareness and perceived utility motivate preventive action (Adekoya et al., 2023; Grace et al., 2021).

Conversely, perceived barriers had a significant negative influence on adoption, emphasizing the constraining role of cost, inadequate storage facilities, and limited space. Structural and economic barriers have consistently been identified as major obstacles to effective mold and mycotoxin control in sub-Saharan Africa (Udomkun et al., 2020; Hoffmann et al., 2022).

Subjective norms significantly predicted safe mold management, highlighting the importance of social expectations, community influence, and household norms in shaping behavior. This supports TPB-based evidence that social pressure and collective practices strongly affect food handling behaviors in rural settings (Morris et al., 2021). Attitudes, although generally positive, were not statistically significant, suggesting that favorable perceptions alone are

insufficient without social reinforcement and enabling conditions.

Education level and extension contact further increased the likelihood of adoption. Households with higher educational attainment and access to extension services were better equipped to understand mold risks and implement appropriate storage technologies. This finding reinforces the role of agricultural extension and public health communication in improving food safety practices (FAO, 2022; Ricker-Gilbert & Jones, 2023).

Overall, the results demonstrate that safe mold management practices among households in Jigawa State are shaped by an interaction of psychological factors (self-efficacy, intention, subjective norms), perceived risks and benefits, and structural support systems. These findings confirm the value of integrating HBM and TPB constructs when designing context-specific interventions to reduce mold contamination and improve food safety in rural Nigerian settings.

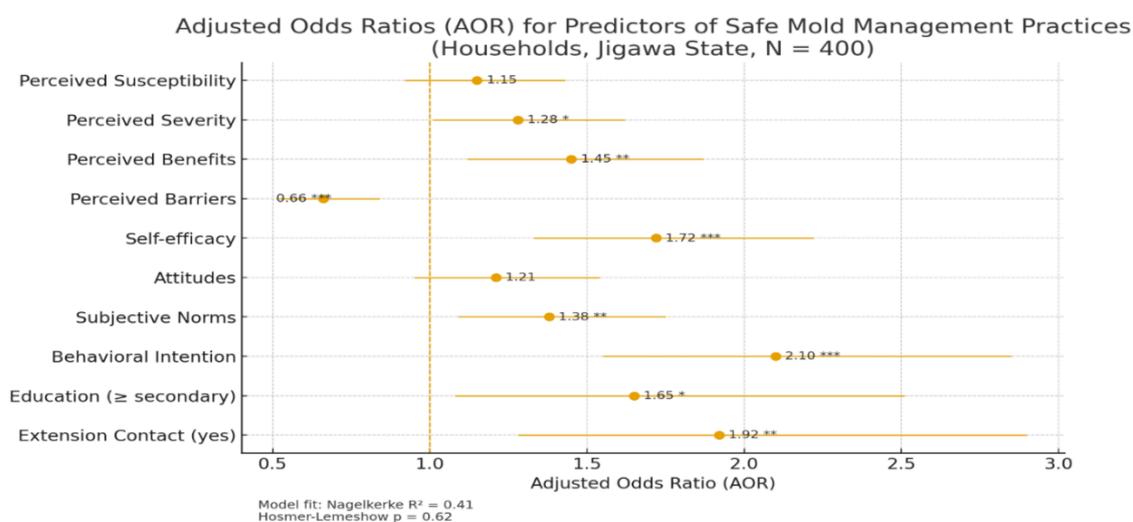


Figure 7: Adjusted Odds Ratios for Prediction of Safe Mold Management Practices
Source: Field Survey, 2025

CONCLUSION

This study provides empirical evidence on the determinants of safe mold management practices among households in Jigawa State using an integrated Health Belief Model and Theory of Planned Behavior framework. The findings demonstrate that household adoption of safe mold management practices is primarily driven by behavioral intention, which is strongly influenced by self-efficacy, perceived severity of mold contamination, perceived benefits of preventive practices, and subjective social norms. In contrast, perceived barriers related to cost, labor, and limited storage infrastructure significantly hinder adoption, while perceived susceptibility alone does not sufficiently motivate behavior change. The convergence of results from both multivariate logistic regression and Structural Equation Modeling underscores the robustness of the findings and validates the applicability of the integrated HBM-TPB framework in explaining food safety behavior in low-resource, agrarian settings. Education and extension contact were found to play critical enabling roles by enhancing self-efficacy and facilitating the translation of intention into actual practice. These results highlight that awareness of mold contamination, although necessary, is insufficient to drive sustained behavior change without adequate confidence, social reinforcement, and institutional support.

Overall, the study concludes that effective mold risk reduction at the household level requires a holistic approach that simultaneously addresses psychological determinants, social influences, and structural constraints. The integrated behavioral framework adopted in this study offers a comprehensive and context-appropriate basis for designing targeted interventions aimed at improving food safety and public health outcomes in Jigawa State and similar settings across sub-Saharan Africa.

RECOMMENDATIONS

Based on the findings of this study, the following recommendations are proposed:

- i. **Strengthening Agricultural Extension Services:** Government and development partners should enhance the reach and quality of agricultural extension services with a specific focus on mold prevention and safe post-harvest practices. Practical demonstrations, regular follow-up visits, and farmer-to-farmer learning platforms should be prioritized to improve household self-efficacy and sustained adoption.
- ii. **Promotion of Affordable Storage Technologies:** Policies should support the dissemination of affordable, locally adaptable storage technologies such as hermetic bags and improved granaries. Subsidies, cooperative purchasing schemes, and access to micro-credit can

- help reduce financial barriers faced by low-income households.
- iii. **Behavior-Change Communication Interventions:** Food safety programs should incorporate behavior-change communication strategies grounded in behavioral theory, emphasizing the serious health consequences of mold exposure, the benefits of preventive practices, and positive social norms within communities.
 - iv. **Community-Based and Norm-Focused Approaches:** Interventions should leverage existing social structures, including community leaders, women's groups, and religious institutions, to reinforce positive subjective norms and collective responsibility for safe food handling.
 - v. **Integration into Public Health and Rural Development Policies:** Mold and food safety education should be integrated into broader public health, nutrition, and rural development initiatives to ensure coordinated and sustainable impact.
 - vi. **Future Research:** Longitudinal and intervention-based studies are recommended to assess causal pathways and evaluate the effectiveness of theory-driven behavior change interventions in reducing mold contamination and associated health risks.
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