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Research Article

# Knowledge, Attitudes, and Practices of Grain and Legume Vendors Regarding Mycotoxins and Toxigenic Molds in Mali

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## Abstract

Mali relies heavily on agriculture and requires an annual growth rate of 6% or more in this sector to achieve sustainable development overall. However, the contamination of essential cereals and legumes—key to reducing food insecurity in Africa—exacerbated by the proliferation of toxigenic fungi, represents a major constraint to the availability of safe food. The objective of this study was to assess the knowledge, attitudes, and practices of cereal and legume vendors regarding mycotoxins and toxigenic molds in Mali. This was a descriptive cross-sectional study conducted in 2024, involving 240 cereal and legume vendors across key production areas. Data were collected using questionnaires administered to the vendors. Among the respondents, 42.5% were aged between 36 and 45 years, with a minimum age of 15 and a maximum age of 75. Males made up the majority, accounting for 87.92%. Most vendors had a primary education level (24.16%), while 3.33% had higher education. Knowledge of fungi and mycotoxins was reported by 65% and 49% of respondents, respectively. Storage facilities were available for 96% of respondents, with 90% storing products for more than three months. Additionally, 52% of respondents dried their harvests directly in the field. Comprehensive, multisectoral approaches are needed to address the complex issues of fungi and mycotoxins, improve health outcomes, and enhance the incomes and livelihoods of farmers, farming households, and Malian consumers.

## Keywords

Fungi, Mycotoxins, Toxigenic, Cereals, Legumes

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# 1. Introduction

Mali relies heavily on agriculture, requiring an annual growth rate of 6% or more in this sector to achieve sustainable development. However, the contamination of essential cereals and legumes—key to reducing food insecurity in Africa—is exacerbated by the proliferation of toxigenic fungi, posing a major constraint to the availability of safe food. According to the Food and Agriculture Organization [7], approximately one-quarter of global crops are significantly contaminated by mycotoxins, resulting in estimated global losses of 25%. This contamination affects the export of agricultural products such as peanuts, pistachios, cottonseeds, cereals, and their derivatives from developing countries [4] and [6]. It is also worth noting that trade in these mycotoxin-sensitive products amounts to approximately 100 million tons annually, with 20% originating from developing countries [8].

Mycotoxins are secondary metabolites produced by molds that grow on plants in the field and during storage. Numerous species of filamentous fungi, primarily from the genera *Penicillium*, *Aspergillus*, and *Fusarium*, are known to contaminate agricultural products. These fungi are present in ambient air, soil, and crops, and they can develop on crops before or after harvest, particularly during storage prior to industrial processing. Their presence leads to changes in organoleptic properties, reduced nutritional quality, and decreased volume of harvested grains. These molds can also grow on dried foods and feeds, including cereals, seeds, nuts, dried fruits, dried yams, and, according to some authors, dried cassava-based products. They are also found in dried meat and fish [2, 3, 10, 5].

Food safety indicators will remain difficult to achieve in Africa as long as contamination by molds and mycotoxins remains unresolved. In 2011, the 7th Partnership Platform for the Development of Global African Agriculture highlighted the urgent need to mitigate mycotoxin contamination by recommending the establishment of consumption standards.

In Mali, [1] measured aflatoxin levels exceeding 20 mg/kg in over 33% of fields in the studied regions, with peanuts and maize being the target crops. This level is 1,000 times higher than European standards and poses significant health risks to both humans and animals. Further research revealed that in some regions, aflatoxin contamination levels exceeded 500 mg/kg in certain food products, such as peanuts [1]. These crops are staples in the national diet and are also important commercial products. When ingested in sufficient quantities, mycotoxins can cause severe diseases in humans and livestock, underscoring the need to reduce contamination risks [9].

Thus, the aim of this study is to assess the knowledge, attitudes, and practices of cereal and legume vendors in Mali regarding mycotoxins and toxigenic molds. By identifying gaps in awareness and practices, this research aims to propose solutions to reduce contamination risks and improve food safety in Mali.

# 2. Materials and Methods

*Study Location.* This survey was conducted in Mali, specifically in key regions known for cereal and legume production that supply the city of Bamako: the Ségou, Koulikoro, and Koutiala regions. The climatic and environmental conditions in these areas are highly conducive to mold growth, creating a practically certain risk of food contamination. The rationale for conducting this study in cereal and legume production zones was to assess the knowledge, attitudes, and practices of vendors regarding mycotoxins and toxigenic molds in Mali.

## 2.1. Type of Survey

This is an evaluative cross-sectional study assessing the knowledge, attitudes, and practices of cereal and legume vendors regarding mycotoxins and toxigenic molds in Mali.

## 2.2. Sampling

The sample consisted of cereal and legume vendors from the selected localities during the study period. The total number of vendors surveyed was 240 individuals.

## 2.3. Inclusion Criteria

All vendors from various markets in the different cereal and legume production areas, as well as the six (06) communes of Bamako, were included in the survey.

## 2.4. Exclusion Criteria

Vendors outside the cereal and legume production areas and the six (06) communes of Bamako, as well as those who refused to participate in the study, were excluded.

## 2.5. Vendor Selection

Sampling was exhaustive, including all vendors who met the inclusion criteria.

## 2.6. Data Collection Technique

This prospective survey was conducted as a single cross-sectional study. We carried out the study by administering a questionnaire to cereal and legume vendors. The questionnaire was designed to be simple, ensuring it was easily understood by the vendors, and contained few open-ended questions to facilitate completion and simplify data analysis.

The form was printed double-sided on A4 paper for its economic advantages and to reduce any inconvenience for the vendors. The questionnaire was divided into three distinct sections: the first section collected general information (sociodemographic characteristics), the second focused on the vendors' knowledge, attitudes, and practices regarding cereals

and legumes, and the third addressed storage and transportation methods for cereals and legumes.

## 2.7. Ethical Considerations

Respect for confidentiality and human dignity was ensured throughout the study. The objectives of the research and data collection procedures were explained to the cereal and legume vendors. Participation was voluntary, and informed consent was obtained from all participants.

## 2.8. Statistical Analysis

Data were entered into Excel 2019, checked for completeness and consistency, and then analyzed using SPSS version 20. This software allowed for the detection and removal of inaccurate data and facilitated descriptive and bivariate statistical analyses ($p < 0.05$). Results were presented in clear tables and graphs to ensure easy interpretation.

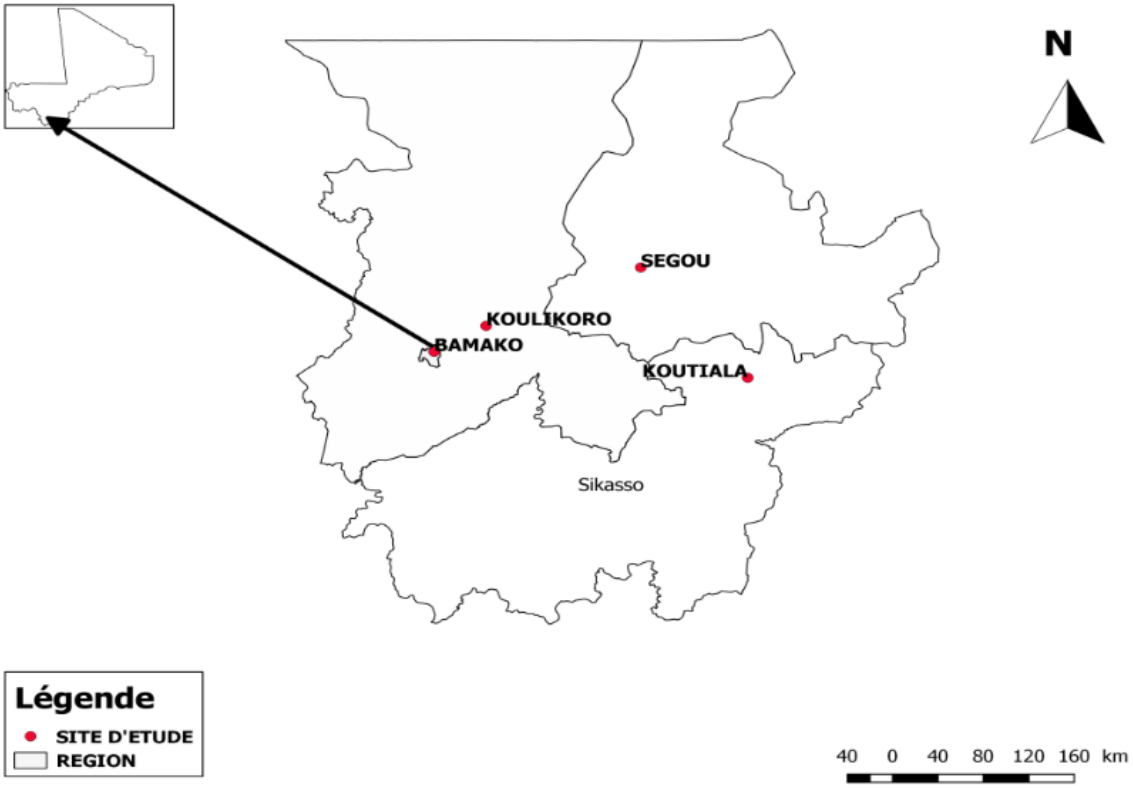


***Figure 1.*** *Map illustrating the different survey areas.*

# 3. Results

*Sociodemographic Characteristics.* The distribution of respondents according to their age group is presented in Table 1. Among the surveyed vendors, 42.5% were between 36 and 45 years old, which may be attributed to the high level of activity within this age group. The minimum age was 15 years, while the maximum age was 75 years.

***Table 1.*** *Distribution of vendors by age.*

| Age (in years) | Frequency | Percentage (%) |
|---|---|---|
| 15 to 25 years | 17 | 7.1 |
| 26 to 35 years | 60 | 25.0 |
| 36 to 45 years | 102 | 42.5 |
| 46 to 55 years | 46 | 19.2 |
| 56 to 65 years | 13 | 5.4 |
| 66 to 75 years | 2 | 0.8 |
| Total | 240 | 100 |

Figure 2 illustrates the distribution of vendors by gender. The results show that out of the 240 respondents, 211 were male, representing 87.92%, while 29 were female, accounting for 12.08%. This significant male predominance could be

explained by the fact that the majority of stores are managed by men, or more broadly, by the traditional roles assigned to men in society.

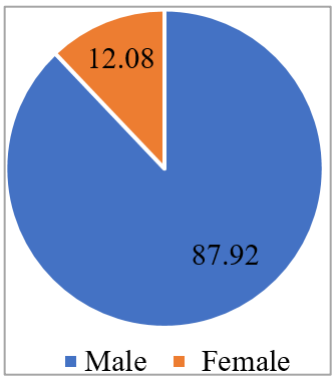


***Figure 2.*** *Distribution of vendors by gender.*

Table 2 presents the distribution of respondents according to the cities surveyed. The analysis of Table reveals that a total of 240 vendors were surveyed across the four study regions, with 60 respondents per zone. Additionally, 10 vendors were surveyed in each of the six communes of the Bamako district.

***Table 2.*** *Distribution of respondents by city.*

| City | Number of Respondents | Percentage (%) |
|---|---|---|
| Bamako | 60 | 25 |
| Koulikoro | 60 | 25 |
| Koutiala | 60 | 25 |
| Ségou | 60 | 25 |
| Total | 240 | 100 |

The distribution of respondents by gender and education level is summarized in table 3. Among the 211 male respondents, 49 attended Quranic school, 48 had a primary education level, and 7 had a higher education level. Among the 29 female respondents, 10 had a primary education level, and 9 had a secondary education level. This survey highlights that the majority of stores are managed by traders with low levels of education: primary (24.16%) and secondary (21.25%). These percentages can be explained by the low socio-professional integration rates for individuals with primary and secondary education levels.

***Table 3.*** *Distribution of respondents by gender and education level.*

| Gender | Higher | Secondary | Primary | Quranic | Literacy | None | Total |
|---|---|---|---|---|---|---|---|
| Male | 7 | 42 | 48 | 49 | 20 | 45 | 211 |
| Female | 1 | 9 | 10 | 5 | 2 | 2 | 29 |
| Total | 8 | 51 | 58 | 54 | 22 | 47 | 240 |

Figure 3 illustrates the overall distribution of respondents by their education level. The analysis of the results in Figure 3 shows that the majority of respondents had a primary education level, accounting for 24%, followed by Quranic education at 23%. Secondary education was reported by 21% of respondents, while 20% had no formal education. The lowest percentages were observed for literacy programs (9%) and higher education (3%).

Figure 4 illustrates the overall distribution of respondents by their knowledge of fungi and mycotoxins. These results indicate that 65% of respondents are aware of fungi, while 35% are not. Regarding mycotoxins, 51% of respondents confirmed having knowledge, whereas 49% reported no awareness. This disparity may be attributed to the limited educational exposure and low levels of formal schooling among the surveyed population.

Table 4 presents the distribution of respondents according to their education level and knowledge of fungi, mycotoxins, and aflatoxins. An analysis of the data reveals a clear correlation between education level and familiarity with these scientific concepts. Indeed, individuals with higher education levels (higher, secondary, or primary) demonstrate greater awareness of these concepts, while those with lower education levels or no formal schooling often remain unfamiliar.

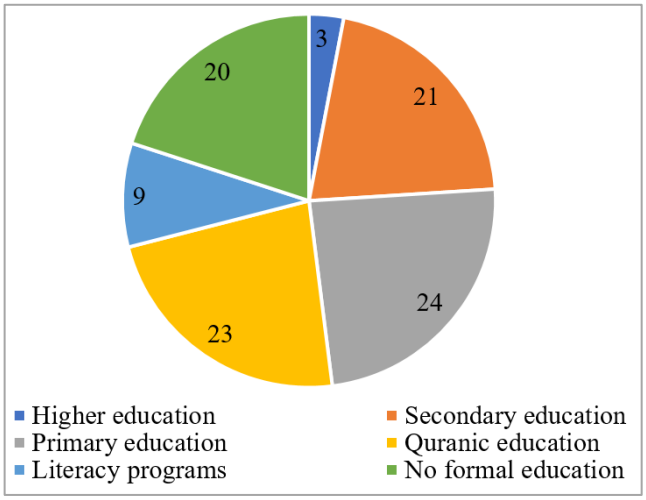


***Figure 3.*** *Overall distribution of respondents by their education level.*

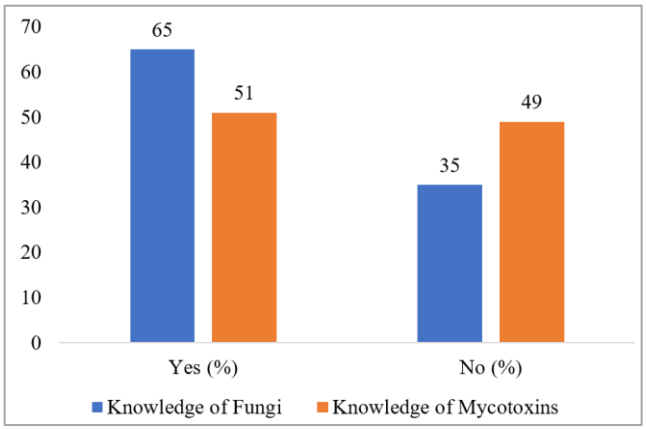


***Figure 4.*** *Knowledge of fungi and mycotoxins.*

Regarding fungi, the results indicate that 87.5% (7/8) of individuals at the higher education level, 82.4% (42/51) at the secondary level, and 74.1% (43/58) at the primary level report having heard of fungi. This positive trend is likely due to access to scientific information through formal education. However, for individuals who attended Quranic schools or had no formal education, the proportions are significantly lower: only 48.1% (26/54) in the first case and 38.3% (18/47) in the second. These gaps highlight the limitations of knowledge transmission in these specific educational contexts.

Concerning mycotoxins, the results follow a similar trend. Thus, 62.5% (5/8) of individuals with a higher education level, 58.8% (30/51) at the secondary level, and 51.7% (30/58) at the primary level are aware of mycotoxins. In contrast, this proportion drops significantly among individuals who attended Quranic schools (42.6% (23/54)) and those without formal education (34% (16/47)). This difference once again underscores the importance of formal education in disseminating scientific knowledge.

For aflatoxins as well, higher education levels show better awareness. It is observed that 62.5% (5/8) of individuals at the higher education level, 50.9% (26/51) at the secondary level, and 50% (29/58) at the primary level report having heard of aflatoxins. However, among individuals from Quranic schools (40.7% (22/54)) and those without formal education (31.9% (15/47)), the proportions remain low. This trend confirms that lower or nonexistent education levels are associated with increased unfamiliarity with complex topics like aflatoxins.

Overall, the data shows that 64.6% (155/240) of respondents are aware of fungi, 51.2% (123/240) know about mycotoxins, and 48.3% (116/240) have heard of aflatoxins. These results not only highlight the direct influence of education level on awareness of health risks but also emphasize the need to strengthen targeted information campaigns to address gaps observed among less-educated groups. In conclusion, education appears to be an essential lever for improving understanding and prevention of risks related to toxic fungi and aflatoxins.

***Table 4.*** *Distribution of Respondents by Education Level and Knowledge of Fungi, Mycotoxins, and Aflatoxins.*

| Education Level | Have you heard of fungi? | | | Have you heard of mycotoxins? | | | Have you heard of aflatoxins? | | |
|---|---|---|---|---|---|---|---|---|---|
| | Yes | No | Total | Yes | No | Total | Yes | No | Total |
| Higher | 7 | 1 | 8 | 5 | 3 | 8 | 5 | 3 | 8 |
| Secondary | 42 | 9 | 51 | 30 | 21 | 51 | 26 | 25 | 51 |
| Primary | 43 | 15 | 58 | 30 | 28 | 58 | 29 | 29 | 58 |
| Quranic | 26 | 28 | 54 | 23 | 31 | 54 | 22 | 32 | 54 |
| Literacy | 19 | 3 | 22 | 19 | 3 | 22 | 19 | 3 | 22 |
| None | 18 | 29 | 47 | 16 | 31 | 47 | 15 | 32 | 47 |
| Total | 155 | 85 | 240 | 123 | 117 | 240 | 116 | 124 | 240 |

Figure 5 provides an overview of the presence of storage facilities and the duration of storage in these facilities. The results from Figure 4 show that 96% of respondents report having a storage facility, while 90% of respondents indicate a storage duration of no more than three months.

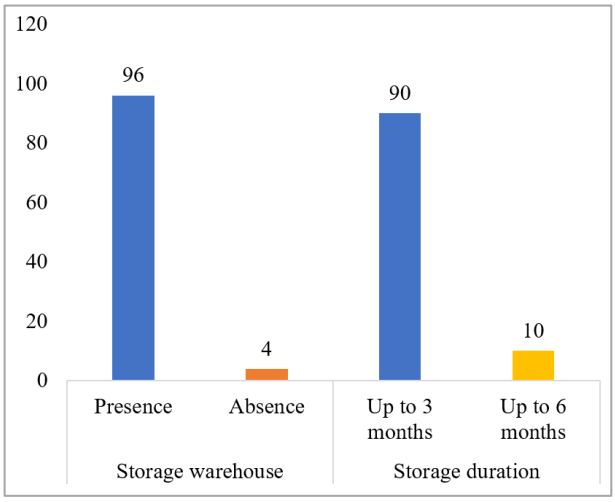


***Figure 5.*** *Storage duration and Storage warehouse (%).*

Figure 5 shows the frequency of drying locations for cereals and legumes. The survey results indicate that 52% of respondents dry their cereals and legumes in the field, compared to 24% who dry them both in the field and at home. Proportions of 9%, 8%, and 7% were obtained for drying at home, in storage facilities, and under other drying conditions, respectively.

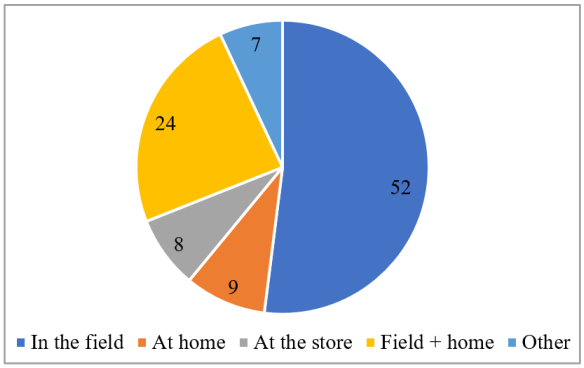


***Figure 6.*** *Frequency of drying locations for cereals and legumes.*

## 4. Discussion

The contamination of food by mycotoxins remains a major public health concern, particularly in developing countries [11]. However, the knowledge, awareness, and practices of rural farmers regarding this issue remain insufficiently explored, especially in sub-Saharan Africa [2]. In Mali, although research on mycotoxins is still in its early stages, it shows promising results. Some local studies have helped fill critical information gaps, with data deemed relevant for public interest [10].

The findings of this study reveal a strong predominance of respondents aged 36 to 45 years (42.5%), a trend also observed in Cameroon by [16]. This age group, often associated with increased professional experience and economic stability, is overrepresented in the agricultural sector. In contrast, younger individuals (15-25 years) are underrepresented (7.1%), reflecting a regional trend where they have limited access to formal economic opportunities [12].

Regarding gender, a strong male predominance (87.92%) is observed, likely due to sociocultural norms that traditionally assign primary economic roles to men. However, a Cameroonian study [16] notes a more balanced distribution (50.3% women), highlighting the importance of policies aimed at promoting women's economic inclusion.

The data indicate that 51.2% of respondents are aware of mycotoxins, and 48.3% are familiar with aflatoxins—levels slightly higher than those reported in Burkina Faso (12%) by [16]. This difference could be explained by better awareness in urban areas of Mali compared to rural areas in Burkina Faso. Similarly, a Ugandan study [17] shows that 96.2% of actors in the cassava value chain do not understand the term "mycotoxins," but 56% are aware of aflatoxins.

However, the low levels of knowledge among individuals who attended only Quranic schools (42.6%) or had no formal education (34%) remain concerning. These findings are consistent with Nigerian studies [13] and [14], which highlight that a lack of education limits access to crucial scientific information. According to [17], formal education programs play a key role in disseminating knowledge about aflatoxins and their health impacts.

Although 96% of vendors have storage facilities, 90% of products remain there for less than three months. This short storage duration reduces the risk of mycotoxin contamination, as confirmed by a study conducted in Ghana [15]. However, drying practices remain problematic: 52% of respondents dry their products directly in the field—a practice also observed in Ethiopia [18]. This type of drying exposes foodstuffs to conditions conducive to the proliferation of toxic fungi, thereby increasing the risk of aflatoxin contamination.

The use of storage facilities for drying remains marginal (8%), confirming the findings of previous studies [18]. These rudimentary practices underscore the importance of strengthening the capacities of farmers and traders in post-harvest management, in line with FAO recommendations [12].

## 5. Conclusion

Comprehensive, multisectoral approaches are necessary to

address the complex issue of aflatoxin contamination and improve the health, incomes, and livelihoods of farmers, farming households, and African consumers. A global aflatoxin control program will include a series of complementary components, including: effective policies, standards, and regulations; actionable information for policymakers derived from economic, food safety, and health assessments; campaigns to increase demand for safe and high-quality food; the distribution and adoption of better inputs and improved production quality; technological solutions and mechanisms (market-based) to monitor products, regulate quality, and ensure proper storage; access to safe and high-quality food ingredients; and the effective removal of contaminated products and alternative uses for them. Actions must be undertaken at all levels (continental, national, regional, and local) to reduce the prevalence of aflatoxin and exposure to it across Africa.

## Abbreviations

| | |
|---|---|
| ACE-B | African Center of Excellence in Bioinformatics |
| LCV | Central Veterinary Laboratory |
| USTTB | University of Sciences, Techniques and Technologies of Bamako |
| ISA | Institute of Applied Sciences |

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## Conflicts of Interest

The authors declare no conflicts of interest.

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