Traders' and smallholder farmers' knowledge, attitudes, and practices towards groundnut aflatoxin contamination in Central Malawi

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Executive summary

The groundnut sector in Malawi has the potential to improve smallholder food security and diversify agricultural production as demonstrated by recent increases in production volume, area planted, and share of the groundnut produce marketed. However, groundnuts carry risks of aflatoxin contamination which not only endangers the health of humans and livestock that consume contaminated nuts, but also hinders access to lucrative domestic and international markets that enforce maximum aflatoxin thresholds.

Using primary survey data collected from smallholder farmers and traders in Kasungu and Lilongwe Agricultural Development Divisions, this study analyses the relationships between aflatoxin knowledge and (i) adoption of aflatoxin-reducing practices and (ii) attitudes towards consumption of affected groundnuts. Our analysis shows that traders exhibit higher overall aflatoxin knowledge, especially in post-harvest practices. Both farmers and traders expressed serious concerns about adults and children under five consuming mouldy groundnuts or livestock products from animals that have been fed moulded groundnuts. Aflatoxin test results on groundnut samples show that groundnuts from traders generally have higher average aflatoxin levels compared to farmers' groundnuts.

Our regression analysis reveals positive correlations between knowledge of aflatoxin and attitudes towards aflatoxin minimising practices. For both farmers and traders, there is a positive association between overall knowledge and adoption of practices that reduce aflatoxin contamination. Specifically, possessing knowledge about proper farming practices such as early planting correlates positively with the adoption of aflatoxin preventive measures or practices. Among traders, increased aflatoxin awareness is linked to better practices. Moreover, traders' awareness that insect-damaged groundnuts encourage mould formation aligns positively with their overall practices. When examining attitudes, both smallholder farmers and traders with extensive aflatoxin knowledge tend to hold attitudes that consumption of mouldy groundnuts is not safe. Furthermore, specific knowledge types like timely harvesting and proper shelling methods also display significant positive associations with attitudes.

Three crucial policy insights emerge from the study. First, there is need to strengthen extension services by providing more training to extension agents on aflatoxin risks and mitigation practices – e.g., timely planting, crop rotation, weed and pest control, optimal planting densities, timely harvesting, thorough drying to reduce moisture content, recommended shelling practices, and storage in well-ventilated conditions – and encouraging transfer of that information to smallholders, perhaps by group training or by utilizing farmer-to-farmer mechanisms. Secondly, recognizing that knowledge alone does not shape trader practices, further research is required to understand how market environments impact trader practices. Higher levels of aflatoxin amongst traders may be due to other factors such as prolonged exposure to high levels of humidity during storage, poor handling during transportation, and mixing of groundnuts from different sources. This may require investigating how local practices can align with international aflatoxin standards, thereby improving access to markets. Lastly, our research shows that there is limited necessity for knowledge interventions related to storage practices, as both smallholder farmers and traders predominantly adhere to recommended practices in this domain, as evidenced by most respondents surveyed. Instead, emphasis should be placed on awareness campaigns that emphasise aflatoxin knowledge and the health risks associated with consuming moulded groundnuts or livestock products from animals fed with moulded groundnuts.

1. Introduction

Groundnut is an important crop in Malawi, being both a food and cash crop, and it has the potential to contribute to the country's agricultural diversification agenda by enhancing food security and generating export revenue (Chintu et al., 2021; National Planning Commission, 2020). Between 2005 and 2022, groundnut production and areas planted increased steadily, while over a similar timeframe commercialization of groundnuts increased from one-third of growers selling a portion of their harvests in 2009 to half in 2019 (Salonga et al., 2023). However, the groundnut sector faces challenges throughout the value chain, from production to marketing and consumption (Chintu et al., 2021). One challenge that has received increasing attention in Malawi is the health risk from aflatoxins, which are toxins produced by mould that affect groundnuts throughout the value chain. In addition to the health risks from consuming affected groundnuts, high concentrations of aflatoxins limit access to lucrative domestic and international markets with premium prices where strict maximum aflatoxin thresholds are enforced (Chintu et al., 2021; Njoroge, 2018; Seid & Mama, 2019; Chen et al., 2022). While researchers, governments, and other stakeholders agree aflatoxin is a problem, there is no consensus on how to mitigate the risks.

This paper provides evidence on aflatoxin knowledge, attitudes, and practices at two levels of Malawi's groundnut value chain – smallholder farmers and traders. These two levels closest to the farm may be especially critical in aflatoxin mitigation and, given their informality and decentralised nature, may have lower awareness of aflatoxin risks. We seek to identify potential gaps in knowledge and behaviours and to identify which knowledge components are associated with recommended practices to reduce aflatoxin contamination in groundnuts. Specifically, the study seeks to address the following research questions: What is the relationship between aflatoxin knowledge and aflatoxin minimising practices among smallholder groundnut farmers and traders? What is the relationship between aflatoxin knowledge and attitudes toward the safety of consuming groundnuts contaminated with aflatoxin among smallholder farmers and traders? Which specific aspects of aflatoxin knowledge are more strongly associated with the adoption of aflatoxin minimising practices and attitudes towards the safety of consuming aflatoxin-contaminated groundnuts among smallholder groundnut farmers and traders?

Aflatoxin is a toxic substance produced by the fungi called *Aspergillus flavus* and *Aspergillus parasiticus*. There are various types of aflatoxin, such as B1, B2, G1, and G2. B1 is the most hazardous and is associated with liver cancer (Liu & Wu, 2010; Nugraha, et al., 2018), and acute hepatitis (Li et al., 2001; Park et al., 2004). Aflatoxin occurs naturally and contaminates oil seeds (e.g., groundnut, sunflower, and cotton), and cereals like maize and rice (Mohammed et al., 2016; Njoroge et al., 2016). The fungi can spread from soils to host crops that are susceptible to contamination (Tembo et al., 2023). Consumption of any food contaminated with aflatoxin can cause serious health problems to humans, but the health risks are highest for children under five. Health conditions associated with the consumption of food contaminated with aflatoxin occur mostly in tropical developing countries, where temperature and humidity favour growth of the fungus (Kumar and Popat, 2010 & Waliyar, 2015). Consumption of aflatoxin-contaminated feed also poses serious health effects to livestock and fish as they increase mortality and reduce productivity (Tembo et al., 2023).

Aflatoxin contamination can occur at all stages of the groundnut value chain, including production, post-harvest handling and processing on the farm, storage, and marketing (Chintu et. al., 2021; Njoroge, 2018). In general, immature, broken, shrivelled and cracked groundnuts are prone to fungal invasion, especially when in direct contact with the soil or exposed to moisture and high temperatures (Hell & Mutegi, 2011). Thus, production practices leading to fully formed and undamaged groundnuts reduce risk of contamination in farmers' fields. These include timely planting, using healthy seed, optimal plant densities, and limiting weed pressure and insect damage. Likewise, harvest and post-harvest practices that limit contact with the soil and moisture reduce aflatoxin risks. These include harvesting at maturity and not too late or too early, drying groundnuts on plastic sheets or on stalks face up to avoid soil contact, and storing in shells away from moisture and pests. Grading and the removal of damaged groundnuts from healthy groundnuts before storage can reduce contamination (ICRISAT, 2016).

Groundnuts have market potential due to high domestic and global demand, but the increasing rates of aflatoxin contamination affect prospects for international trade. Most countries have maximum aflatoxin contamination thresholds that must be met on imported food crops. The internationally accepted level of total aflatoxin in human foods is less than twenty parts per billion (20 ppb) (Shabeer, et al., 2022). However, the limits vary by country: 3 ppb or lower is the standard in Malawi, compared to 5 ppb in the European Union (EU), 10 ppb in most developing countries, and 20 ppb in the United States of America —USA (Magamba et al., 2017). While enforcement of these standards varies, some important commodities like cereals, oilseeds, and some legumes in sub-Saharan African countries get rejected as a result of high aflatoxin contamination (Wagacha and Muthomi, 2008). In 2005, a shipment of Malawian groundnut exports to Europe was rejected due to high rates of aflatoxin contamination. About 49 percent of groundnuts in local markets and 60 percent in supermarkets in Malawi were found to have aflatoxin levels beyond the minimum set international standards (Emmott & Stevens, 2014). The increase in aflatoxin contamination rates has led to an increase in informal groundnut exports, where regulations regarding aflatoxin contamination are not enforced and where prices received by farmers may be less than the formal export routes.

The risks of aflatoxin contamination can be reduced by training and awareness campaigns aimed at increasing public knowledge about the risks and mitigation measures (Azaman, 2016). Equipping producers and traders with knowledge through training is essential for fostering expertise and understanding of practices that minimise aflatoxin risks (Jacob, 1989; James et al., 2007; Azaman et al., 2016). However, there is limited evidence on the relationships between different components of knowledge, attitudes and implementation of practices that minimise aflatoxin risks. Against this backdrop, this study seeks fill a gap in evidence-based policy recommendations in the context of Malawi by analysing how smallholder farmers' or traders' knowledge of aflatoxin relates to their adoption of aflatoxin-reducing practices; and assessing the role of smallholder farmers' or traders' knowledge of aflatoxin on their attitudes towards aflatoxin. The results reveal three key messages for policy makers and development partners seeking to reduce aflatoxin in Malawi's groundnut value chain. First, strengthened extension services to disseminate information on smallholder farmer practices may improve adoption of aflatoxin reducing practices. In particular, production information including timely planting and harvesting may be important topics. Second, more research is needed to understand the market environments and contexts that may be affecting trader practices towards mould formation. This could include studies to identify how best to align local practices with international aflatoxin standards to enhance market access. Third, there is limited need for knowledge interventions around storage practices, for both smallholder farmers and traders as most respondents demonstrated the recommended practices in those categories.

2. Data sources and methodology

The study uses primary data collected from farming households and traders. Regression analysis is carried out to estimate the relationships between smallholder farmers' or traders' knowledge and their adoption of aflatoxin-reducing practices; and to assess the role of farmers' or traders' knowledge of aflatoxin in their attitudes towards the safety of eating moulded groundnuts or livestock products from animals fed moulded groundnuts.

2.1 Data

The survey was conducted by the MwAPATA Institute (MwAPATA) between 31st October 2022 to 12th November 2022, covering nine Extension Planning Areas (EPAs) randomly selected from Lilongwe and Kasungu Agricultural Development Divisions (ADDs). These areas were chosen because they are the largest production areas for groundnuts in Malawi, based on production data from the Ministry of Agriculture.

The nine EPAs include Bembeke, Chileka, Nthondo, Manjawira, Mvera, Chipala, Chulu, Chiosya, and Mkanda EPAs. Fifty (50) smallholder farmers were randomly selected within each EPA from lists provided by government extension agents. Survey teams also visited markets within each EPA and interviewed groundnut traders. Both the farmer and trader surveys collected data on respondent knowledge of aflatoxin and mould formation in groundnuts as well as respondent attitudes towards consumption of affected groundnuts. The same modules on knowledge and attitudes were used in both surveys, allowing for direct comparisons across farmers and traders. Both surveys also elicited information about practices that can either favour or minimise mould formation in groundnuts, though these questions differed between the two surveys according to their roles in the value chain. For the farmers, we collected detailed information on production practices and post-harvest practices. For traders, we asked questions about price differentiation, sorting, and storage.

A total of 444 smallholder farmers were interviewed — 50 farming households each were interviewed from Chileka, Chioshya, Chipala, and Chulu EPAs; 49 households were interviewed from Manjawira, Nthondo and Mkanda EPAs while 46 farmers were from Bembeke EPA (see Table A1 in the appendix). A total of 160 traders were interviewed across various markets in Kasungu and Lilongwe ADDs. The traders were distributed as follows: Kasungu had 8 traders, Chatoloma 14, Mkanda 9, Kapiri 5, Kamwendo 1, Mchinji 8, Thete 6, Chimbiya 5, Lizulu 1, Tsangano Turn Off 27, Kasungu other markets 37, Mchinji other markets 24, Dedza other markets 12, and Ntcheu other markets 3 (see Table A1).

In addition to the interviews, MwAPATA purchased small samples of groundnuts from smallholder farmers and traders to test for aflatoxin levels. In total, we bought 131 samples from farmers and 100 from traders for aflatoxin testing at Agri Input Suppliers Limited based in Kanengo, Lilongwe. The tests were carried out using the enzyme-linked immunosorbent assay (ELISA) method which is widely used due to its accurate detection of aflatoxin and its capability to detect low aflatoxin concentrations (see Van Hengel et al., 2007; Hosseini et al., 2018). The procedure detects Aflatoxin type B1. Most regulatory limits on aflatoxin tend to focus on B1 because it is the most commonly encountered aflatoxin in contaminated food, most toxic and potent carcinogenic aflatoxin type (Benkerroum, 2020; Jallow, et al., 2021).

2.2 Computation of practice, knowledge and attitude scores

2.2.1 Practice score

For each smallholder farmer or trader, we calculate a score of aflatoxin management practices. The score is designed to be higher when the number of practices that minimise aflatoxin levels in groundnuts is higher, that is, it is increasing in better practices. For farmers, the practices included methods used to dry groundnuts, whether groundnuts were protected from rain after harvest, groundnut threshing methods, whether the farmers wetted the groundnuts before shelling, where the groundnuts were stored (e.g., in house, on roof, open space, etc.), how the groundnuts were stored (e.g., in bags, in heaps, in woven crib, etc.), whether the farmers graded the groundnuts, production practices (timely planting, appropriate spacing, weed control and timely harvesting). Recommended (or better) practices were assigned a value of 1 and other practices (i.e., not recommended) were assigned a value of 0. For each farmer, a score was calculated for each practice score and then summing the each of the scores into one overall farmer practice score (see Table A2). For traders, the variables used to compute a practice score included methods used to store groundnuts (e.g., in bags, open heaps) where the groundnuts are kept (in store houses, covered area, etc.); whether traders shell groundnuts after buying but prior to selling and methods used to shell (e.g., hand shelling by hammering, shelling by machine); whether or not traders wetted the groundnuts before shelling; whether the traders graded the groundnuts before selling; whether or not traders offered or received prices based on groundnut quality (see Table A2).

2.2.2 Knowledge score

Smallholder farmers' and traders' knowledge of aflatoxin was assessed through the same five key questions and, like practices, we create a knowledge score that is increasing in correct responses to those questions (see Table A3). First, we asked if respondents could identify what aflatoxin was. Accepted correct responses were a fungus or moulded groundnuts, which we assigned a value of "1", otherwise a value of "0" was assigned. Second, respondents were asked, about which duration of groundnut seed is most likely to suffer from moulding risks (such as late maturity (130 days); medium maturity (110 days); early maturity (90 days); don't know), holding other factors equal, with the correct response of late maturity receiving a value of "1". The third, fourth, and fifth questions were each open-ended and scored similarly. Third, we asked respondents if they knew the major environmental factors which favour forming mould in groundnuts, pre- or post-harvest. Fourth, we asked what measures respondents knew for preventing moulding in groundnuts – during production (pre-harvest). Fifth, we asked about which measures they knew for preventing moulding in groundnuts post-harvest. In each of these three open-ended questions, respondents could list multiple responses and each correct response was given a value of "1" in the knowledge score. By framing the questions as open-ended, we minimise the possibility of respondents answering correctly just by guessing (e.g., in a true/false question someone that does not know the answer will choose the correct response with 50 percent probability). Given the importance of these questions in understanding and preventing aflatoxin formation in groundnuts, these questions should have a higher weight which they do by construction. An overall farmer or trader score was computed by summing the individual knowledge scores. Thus, higher scores represent better knowledge.

2.2.3 Attitude score

For each farmer or trader, an attitude score was computed based on individual attitudes held by farmers and traders towards aflatoxin based a set of four questions (Table A4). The questions included “Is it safe for adults to eat partially moulded groundnuts?”; “Is it safe for children to eat partially moulded groundnuts?”; “Is it safe for adults to eat animal products from animals fed moulded groundnuts?”; and “Is it safe for children under five to eat animal products from animals fed moulded groundnuts?” The inclusion of the question on children under five is due to their vulnerability or susceptibility to healthy risks which have negative consequences for their long-term growth and development (Soliman et al., 2021). Farmers or traders were provided with a set of four responses to choose from for each question, namely “yes, very safe; assigned 0”; “yes, somewhat safe; assigned 1”; “no, somewhat safe; assigned 2” and “no, very unsafe; assigned 3”. More generally, the “no” responses are considered as good attitudes while the “yes” responses were considered as bad attitudes. For each farmer or trader, a score was calculated for each response and then summing the each of the scores into one overall farmer or trader attitude score. A higher score indicates better attitudes.

2.3 Econometric specification

To test for the relationships between knowledge and (i) practices and (ii) attitudes we use two similar linear probability models (LPMs), where the dependent variables are the practices and attitudes scores, respectively. Although LPMs do not match the data generation process for the dependent variables, they still provide consistent estimates of the average relationships to the independent variables. We estimate the following equations:

$$Practices_i = \alpha_0 + \alpha_1 K_i + \alpha_2 X_i + e_i \quad (1)$$

$$Attitudes_i = \beta_0 + \beta_1 K_i + \beta_2 X_i + \epsilon_i \quad (2)$$

Where $Practices_i$ and $Attitudes_i$ respectively represent the outcome variables for farmer or trader i, namely the practices and attitude scores; α_0 represents the intercept term; K_i represents aflatoxin knowledge score. In order to reduce omitted variable bias, and better isolate the relationship between knowledge and practices from other confounding factors, our analysis includes covariate control variables X_i. The control variables include access to extension by a farmer, age of household head or trader; household size, sex of household head or trader; level of education; years growing groundnuts or trading groundnuts (see Table A5 for details). The error terms are respectively represented by e_i and ϵ_i .

Knowledge of aflatoxin is the key determinant in both regressions because it is thought to influence the actions, decisions and practices of farmers and traders. Farmers who have the right knowledge about aflatoxin may be more likely to adopt right practices (e.g., proper drying and storage techniques) that can minimise aflatoxin contamination in groundnuts or may have stronger attitudes towards consumption of affect groundnuts. While the coefficient α_1 will show us whether a higher knowledge score is associated with higher practices scores, it will not reveal any detail about what knowledge components have stronger or weaker relationships to practices. To address that flaw, we extend models (1) and (2) by replacing the overall knowledge score with sub-scores for each knowledge question asked.

3. Results and discussion

3.1 Characteristics of smallholder farmers and traders interviewed

Table 1 provides key statistics for the farming households and traders interviewed and their Characteristics. Data shows that 80 percent of the surveyed farming households were headed by males, with an average household size of 4.94. The average age of household heads was 45.34 years and their farming experience averaged 6.14 years. The household head of farming households attended an average of 5.62 years of schooling, with the highest qualification attained distributed as follows: 76 percent reported having no formal education, 13 percent completed primary school, 7 percent achieved a Junior Certificate of Education (JCE), and 4 percent obtained a Malawi School Certificate of Education (MSCE). About 22 percent of the smallholder farmers reported having access to extension services. On average, the farmers cultivated 1.30 hectares of land in 2022.

Table 1: Summary characteristics of smallholder farmers (N=444) and traders (N=160)

Variable	Mean	SD	Mean	SD

Male (i)	0.80	0.40	0.87	0.34
Age	45.34	15.12	35.16	8.79
Household size	4.94	2.06	n/a	n/a
Years of schooling attended	5.62	3.47	9.11	3.12
Highest qualification attained				
None (i)	0.76	0.43	0.41	0.49
Completed primary school (i)	0.13	0.34	0.12	0.32
Junior Certificate of Education (JCE) (i)	0.07	0.25	0.21	0.41
Malawi School Certificate of education (MSCE) (i)	0.04	0.19	0.27	0.44
Access to extension services	0.22	0.41	n/a	n/a
Land cultivated in 2022 (Ha)	1.30	0.87	n/a	n/a
Experience (years)	6.14	3.27	6.07	3.70
Registered business	n/a	n/a	0.29	0.46
Trader type				
Small mobile trader (no permanent location	n/a	n/a	0.27	0.44
Permanent shop trader	n/a	n/a	0.71	0.46
Container trader located at fixed point	n/a	n/a	0.03	0.16

(i) denotes indicator variables. Data for farmers are for household head.

Source: Computed from survey data

With respect to traders, data shows that 87 percent of the surveyed traders were male, a higher percentage compared to farmers. The average age of traders was reported to be 35.16 years, suggesting a relatively younger demographic compared to farming household heads. Traders, on average, attended school for 9.11 years, which is higher than the corresponding figure for farmers. With respect to the highest qualification attained, about 41 percent of traders reported having no formal qualifications, 12 percent reported completing primary school, 21 percent indicated they had a Junior Certificate of Education (JCE), and 27 percent indicated they had achieved a Malawi School Certificate of Education (MSCE). The average years of experience for traders were comparable to farmers at 6.07 years. About 29.38 percent of the traders interviewed reported to have registered their trading businesses. Additionally, data shows that there are various types of traders, namely small mobile traders without permanent locations accounting for about 26.88 percent of the traders interviewed, 70.63 percent were permanent shop traders, and only 2.50 percent were container traders located at fixed points.

3.2 Smallholder farmer and trader knowledge of aflatoxin and mould formation in groundnuts

Table 2 provides information on the farmers' and traders' knowledge on aflatoxin, namely environmental factors affecting mould formation, production practices for limiting mould formation, information about groundnut varieties more likely to suffer from mould formation, and post-harvest practices for limiting aflatoxin contamination.

Results generally show that traders had higher knowledge of aflatoxin with an overall score of 4.91 compared to farmers, who have a score of 4.43. About 39 percent of farmers correctly identified aflatoxin as a mould or fungus compared to about 32 percent of traders. Traders generally demonstrated a higher understanding with an overall environmental knowledge sub-index of 1.11 compared to farmers whose score averaged 0.89. Farmers and traders exhibited comparable score on production practices that limit mould formation, with farmers scoring 0.93 and traders scoring 1.01 on the production knowledge sub-index. However, a larger proportion of farmers displayed higher knowledge scores that late maturing varieties more likely to experience mould. On knowledge of post-harvest practices that limit aflatoxin contamination, traders tend to have a higher average score of 1.67 in post-harvest knowledge compared to farmers' score of 1.42. This suggests that traders may have a better understanding of practices such as rapid drying, storing methods, and shelling methods to reduce groundnut damage.

Table 2: Aflatoxin knowledge scores and components, farmers and traders

	Farmers (N=444)		Traders (N=160)	
Statement	Average score	SD	Average score	SD
Have knowledge of Aflatoxin	0.39	(0.49)	0.32	(0.47)
Environmental factors that favour mould formation				
Temperature	0.22	(0.42)	0.07	(0.25)
Humidity/ prolonged rain	0.53	(0.50)	0.33	(0.47)
Insects/ pests damage	0.09	(0.29)	0.67	(0.47)
Abundance of fungi	0.05	(0.21)	0.04	(0.19)
Sub-index - Environmental knowledge [0,4]	0.89	(0.81)	1.11	(0.76)
Production practices to limit mould formation				
Early planting	0.13	(0.33)	0.1	(0.30)
Crop rotation	0.12	(0.32)	0.11	(0.31)
Healthy soils/ fertilisation	0.1	(0.30)	0.09	(0.29)

Using new and healthy seed	0.07	(0.25)	0.07	(0.25)
Controlling pests and fungi	0.19	(0.40)	0.23	(0.42)
Timely harvesting of mature groundnut	0.26	(0.44)	0.34	(0.48)
Maintaining optimal plant density	0.06	(0.24)	0.06	(0.24)
Sub-index - Production knowledge [0,6]	0.93	(1.03)	1.01	(0.89)
Late maturing varieties more likely to experience mould	0.38	(0.48)	0.3	(0.46)
Post-harvest practices to limit mould formation				
Rapid drying	0.5	(0.50)	0.58	(0.50)
Dry off the ground/soil	0.21	(0.41)	0.21	(0.41)
Avoiding ground contact at harvest	0.12	(0.32)	0.15	(0.36)
Hand sorting after harvest	0.05	(0.23)	0.06	(0.24)
Storing in a dry place, off the ground	0.44	(0.50)	0.48	(0.50)
Avoid storing in old contaminated bags	0.09	(0.29)	0.14	(0.35)
Appropriate shelling methods to reduce groundnut damage	0.01	(0.11)	0.06	(0.23)
Sub-index - post-harvest knowledge [0,7]	1.42	(1.08)	1.67	(1.13)
Overall knowledge index [0,21]	4.43	(2.81)	4.91	(2.60)

Source: Computed from survey data.

3.3 Smallholder farmer and trader attitudes towards consumption of affected products

Table 3 presents summary data on how smallholder farmers and traders perceived the safety of the consumption of partially moulded groundnuts and livestock products from animals that have been fed moulded groundnuts for both adults and under-five children.

Table 3: Attitudes towards consumption of mouldy groundnuts and livestock fed mouldy groundnuts

	Farmers (444)				Traders (160)			
	Very safe	Somewhat safe	Somewhat unsafe	Very unsafe	Very safe	Somewhat safe	Somewhat unsafe	Very unsafe
Consume mouldy groundnuts								
Adults	5%	5%	6%	85%	6%	4%	9%	82%
Children under 5	3%	5%	5%	87%	4%	4%	9%	83%
Consume livestock fed mouldy groundnuts								
Adults	13%	11%	23%	53%	14%	15%	16%	56%
Children under 5	12%	11%	21%	57%	11%	13%	20%	56%
Average	8%	8%	13%	70%	9%	9%	13%	69%

Source: computed from survey data.

Among both farmers and traders, there is a high level of perception that the consumption of mouldy groundnuts is very unsafe, with a slightly higher percentage expressing concerns about potential health risks for under-5 children compared to adults. Similarly, when it comes to the safety of consuming livestock products fed with mouldy groundnuts, the majority of both farmers and traders considered it very unsafe, suggesting consistent safety perceptions between the interviewed farmers and traders regarding the potential safety associated with the consumption of products derived from livestock fed with mouldy groundnuts.

More generally, a larger share of farmers indicated that the consumption of mouldy groundnuts was very unsafe for adults (85 percent) and children under 5 (87 percent) compared to traders with percentage of 82 percent and 83 percent, respectively.

3.4 Farmer and trader practices related to aflatoxin and mould formation in groundnuts

Smallholder farmers employ a diverse range of practices to mitigate against aflatoxin contamination in groundnuts, during both production and post-production stages (Table 4). The results reveal that a number of recommended practices to mitigate aflatoxin formation in groundnuts are already implemented by a majority of smallholder farmers. The predominant groundnut drying method is the Mandela cock/on plants- loose on the ground with pods facing up, comprising 70.3 percent of the responses. This is a recommended practice as it exposes the pods to the sun for fast drying and keeps pods out of contact with the ground. Other groundnut drying methods include on grass roof (9.0 percent), on iron roof (8.3 percent), and pods only on bare dirt ground (4.1 percent). With respect to storage, the majority of smallholder farmers (94.14 percent) stored groundnuts in the house, with smaller percentages opting for alternative locations such as store house/room (3.38 percent) and woven crib (2.03 percent). The majority of the households stored groundnuts in bags, unshelled (91.67 percent), while 98.65 percent reported using hand shelling as the primary shelling method.

Table 4: Smallholder farmer practices affecting aflatoxin risks

Statement	Percent	SD
Production methods		
Planted on time (before January)	58.3%	(0.49)
Correct interrow spacing (<50cm)	80.6%	(0.40)
More than 1 complete weeding	71.4%	(0.45)
Not late harvest (before May 15)	30.2%	(0.46)
Drying methods		
On plants- loose on ground with pods facing down	2.7%	(0.16)
Mandela cock / on plants- loose on the ground with pods facing up	70.3%	(0.46)
Stacking pole	2.7%	(0.16)
A-Frame	0.7%	(0.08)
Pods only, on bare dirt ground	4.1%	(0.20)
On grass roof	9.0%	(0.29)
On iron roof	8.3%	(0.28)
On reed mat (Mphasa)	0.5%	(0.07)
On mesh sheet	0.5%	(0.07)

On plastic sheet	0.9%	(0.09)
Other methods	0.5%	(0.07)
It rained on groundnuts after harvest	22.5%	(0.42)
Wetted the groundnuts before shelling	15.5%	(0.36)
Storage location		
In house	94.1%	(0.24)
In store house/room (walls and roof)	3.4%	(0.18)
In covered but open-walled area	0.5%	(0.07)
In woven crib (Nkhokwe)	2.0%	(0.14)
Storage method		
In bags, shelled	5.6%	(0.23)
In bags, unshelled	91.7%	(0.28)
In open heap, shelled	0.7%	(0.08)
Shelling method		
Not yet shelled	0.5%	(0.07)
Hand shelling	98.7%	(0.12)
Beating	0.2%	(0.05)
Hand shelling machine	0.2%	(0.05)
Motorised shelling machine	0.2%	(0.05)
Other methods of shelling	0.2%	(0.05)

Source: computed from survey data. Number of observations: 444 farmers

Notably, 22.5 percent of respondents reported that rain fell on the groundnuts after harvest, which would likely encourage mould formation. Furthermore, data indicates that 15.5 percent of respondents wetted the groundnuts before shelling.

Groundnut traders engaged in a variety of practices which have implications on aflatoxin contamination levels (see Table 5). Data shows that a significant percentage of traders (65.4 percent) reported offering different buying prices based on varying groundnut quality, suggesting their commitment to quality control. Additionally, a substantial proportion of traders (66.3 percent) reported offering different selling prices for groundnuts based on their quality, further suggesting some quality assessment in their trading business. About 50.0 percent of the traders that shell groundnut[1] reported wetting groundnuts prior to shelling, a practice that may lead to increased aflatoxin contamination. About 32.5 percent of traders reported sorting and grading groundnuts before selling. These practices suggest that traders practice some quality and food safety standards in the trade of groundnuts. Notably, a majority of groundnut traders interviewed (95.6 percent) opted to store their groundnuts in

[1] Our analysis of the data shows that approximately 22.5% of the traders shell their groundnuts after purchasing them.

bags, and nearly all of them (98.8 percent) stored bags of shelled groundnuts in suitable storage facilities. However, only a small percentage (0.6 percent) store groundnuts in heaps on open ground.

Table 5: Traders' practices related to aflatoxin risks

Statement	Percent	SD
Offer different buying prices based on different quality	65.4%	(0.48)
Wet the groundnuts prior to shelling	50.0%	(0.51)
Sort/grade groundnuts prior to selling	32.5%	(0.47)
Store groundnuts in open heaps	3.8%	(0.19)
Store groundnuts in bags	95.6%	(0.21)
Store shelled groundnut in the house	98.8%	(0.11)

Source: computed from survey data. Number of observations: 160 traders

Table 6 shows average scores for aflatoxin knowledge, attitudes and practices for smallholder farmers and traders. Traders have a significantly higher average knowledge score than farmers. Farmers have a mean knowledge score of 4.01 compared to a score of 4.91 for traders. Overall, the average scores are well below the maximum possible score of 21, but that is partly due to the fact that knowledge was assessed with open-ended questions and respondents were thus less likely to score highly relative to other question types. When it comes to attitudes towards aflatoxin contamination, farmers and traders have similar scores: farmers have a higher attitude score of 9.84 and traders have an average score of 9.73. With the maximum attitude score of 12 being strong perceptions that consuming affected groundnuts and livestock fed affected groundnuts are unsafe, it is apparent that both farmers and traders generally have accurate attitudes towards consumption risks. The practices scores are not comparable across the samples, but farmers had an average score of 5.65 out of a maximum of 9 while traders have an average score of 2.92 out of a maximum score of 7.

Table 6: Aflatoxin knowledge, attitudes and practices scores, farmers and traders

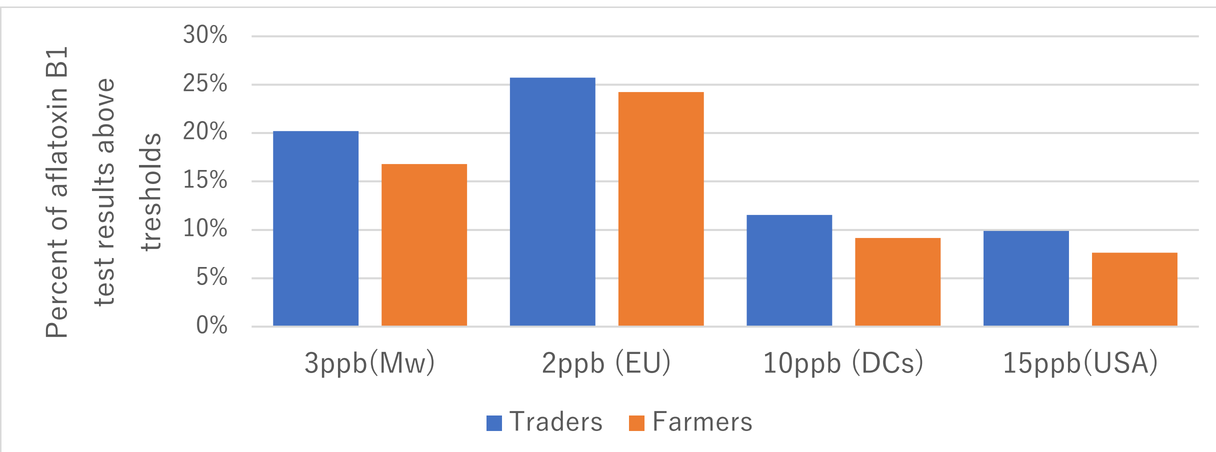
	Farmers (N=444)		Traders (N=160)		Comparison statistics		
Description	Mean	SD	Mean	SD	Diff	t	p-value
Knowledge	4.01	(2.68)	4.91	(2.60)	-0.90	-3.66***	0.000
Attitudes	9.84	(3.10)	9.73	(3.23)	0.12	0.41	0.685
Practices	5.65	(1.18)	2.92	(0.77)	n/a	n/a	n/a[2]

Source: computed from survey data. Practices scores (as described above) are composed of different variables for farmers and traders. Thus, comparison statistics are not included.

3.5 Aflatoxin B1 contamination levels for smallholder farmer and trader samples

Figure 1 presents the share of aflatoxin samples exceeding specified regulatory thresholds in various countries, including Malawi (Mw), the EU, most developed countries (DCs), and the USA.

Figure 1: Percentage of groundnut samples above maximum aflatoxin B1 concentration, farmers and traders



Source: computed from survey data

Generally, a higher share of groundnut samples from traders compared to farmers exceeded the aflatoxin thresholds set in various regions. Among farmers, 17 percent of samples exceeded the 3ppb limit for Malawi, and 24 percent surpassed the 2ppb limit set by the EU. Furthermore, 9 percent and 8 percent of the groundnut samples exceeded the 10ppb and 15ppb limits for most developed countries and the USA, respectively. Traders exhibited a

[2] Practice scores for smallholder farmers and traders are not computed on the same type of questions and therefore not directly comparable.

slightly higher prevalence of aflatoxin B1 levels in the groundnut samples, with 20 percent of the trader samples exceeding the 3ppb limit for Malawi, 26 percent exceeding the 2ppb limit for the EU, 12 percent surpassing the 10ppb limit for most developed countries, and 10 percent exceeding the 15ppb limit for the USA. However, the USA limit for both domestic and imported groundnut is set at 15ppb total aflatoxin, regardless of the type (American Peanut Council, 2020).

3.6 Relationships between aflatoxin knowledge and practices

Tables 7 and 8 show results from our regression analyses of equation (1) for smallholder farmers (columns 1 and 2) and traders (columns 3 and 4). For farmers, the overall knowledge index (KI) is positively associated with higher practices scores (statistically significant at the 5 percent level without controls and the 10 percent level with controls). Thus, higher knowledge is related to improved groundnut practices in mitigate aflatoxin risks at the farm level. However, for traders, the relationship between knowledge and practices is insignificant. This is partly because more than 95 percent of traders appropriately store groundnuts, thus there is little variation in those practices for knowledge to explain. Also, trader practices may be more dictated by the market environment in which they operate rather than their specific knowledge of mould formation. The fact that traders have better storage practices but slightly higher aflatoxin levels is a reflection of the fact that traders' groundnuts are often shelled, which increases the risk of damage and contamination. Additionally, the groundnuts have been transported from the farm, which further increases the risk of damage and contamination.

Table 7: Relationships between knowledge index and practices index, farmers and traders

Sample	Farmers				Traders			
Dep. Var = practices index	(1)		(2)		(3)		(4)	
	Coeff	Z	Coeff	Z	Coeff	Z	Coeff	Z
Overall KI	0.048**	(2.31)	0.040*	(1.90)	0.029	(1.18)	0.012	(0.47)
Controls	No		Yes		No		Yes	
N	444		444		160		160	
R-sq.	0.012		0.058		0.009		0.117	

KI = knowledge(K) index; Z= z statistics. Significance ="* p<.1; ** p<.05; *** p<.01". Control variables for farmers include access to extension, farmer experience in years, land cultivated during the 2022 cropping season, age of household head, household size, gender of household head, educational qualification of household head. Control variables include trader experience in years, age of trader, gender of trader, educational qualification of household head and type of trader.

Table 8 extends our knowledge results by regressing practices on specific knowledge component indices. For farmers, the production knowledge index shows a positive coefficient of 0.135 (significant at the 10 percent level without controls). The postharvest knowledge index shows no significant association and a near zero coefficient. This reflects the limited variation in post-harvest practices as a clear majority of farmers correctly stored their groundnuts. Further analysis (not shown) reveals that knowledge of early planting shows a positive association with practices. Correct knowledge that aflatoxin is a fungus or mould has a large and positive relationship to practices for both smallholder farmers and traders, though estimations are insignificant.

For traders, results show that the production Knowledge Index (KI) has a negative coefficient of -0.126, and it is statistically significant at the 10 percent level, suggesting that traders' knowledge about production practices is inversely associated with their overall practices index. This is in contrast to smallholder farmers, where production knowledge had a positive and significant association. Postharvest Knowledge Index (KI) and the Environmental Knowledge Index (KI) are not significant- a contrast to the results for smallholder farmers which exhibited positive and significant associations between practices and postharvest knowledge index and environmental knowledge index.

Table 8: Relationships between knowledge sub-components and practices index, farmers and traders

Sample	Farmers				Traders			
Dep. Var. = practices index	(1)		(2)		(3)		(4)	
	Coeff	Z	Coeff	Z	Coeff	Z	Coeff	Z
Knowledge sub-components								
Production KI	0.135*	(1.86)	0.103	(1.41)	-0.126	(-1.44)	-0.159*	(-1.86)
Postharvest KI	-0.017	(-0.27)	0.004	(0.07)	0.083	(1.35)	0.021	(0.34)
Environmental KI	0.015	(0.16)	-0.017	(-0.18)	0.084	(0.80)	0.098	(0.93)
Knows aflatoxin	0.172	(1.44)	0.192	(1.58)	0.097	(0.69)	0.172	(1.24)
Seed duration	-0.05	(-0.41)	-0.003	(-0.03)	0.178	(1.29)	0.244*	(1.81)
Controls	No		Yes		No		Yes	
N	444		444		160		160	
R-sq.	0.019		0.064		0.034		0.152	

KI = knowledge(K) index; Z= z statistics. Significance ="* p<.1; ** p<.05; *** p<.01". Control variables for farmers include access to extension, farmer experience in years, land cultivated during the 2022 cropping season, age of household head, household size, gender of household head, educational qualification of household head. Control variables include trader experience in years, age of trader, gender of trader, educational qualification of household head and type of trader.

3.7 Relationships between knowledge and attitudes

The overall Knowledge Index (KI) has a positive and significant relationship to the attitudes score in 3 of the four estimations (Table 9), indicating a strong positive association between knowledge and attitudes towards consumption of aflatoxin affected products. This positive association remains after controlling for smallholder farmer characteristics, with a slightly higher coefficient of 0.259. However, the coefficient approaches zero and is insignificant when trader controls are added to the model.

Table 9: Relationships between knowledge index and attitudes index, farmers and traders

Sample	Farmers				Traders			
Dep. Var. =	(1)		(2)		(3)		(4)	
attitudes index	Coeff	Z	Coeff	Z	Coeff	Z	Coeff	Z
Overall KI	0.249***	(4.64)	0.259***	(3.04)	0.272***	(2.74)	0.012	(0.47)
Controls	No		Yes		No		Yes	
N	444		444		160		160	
R-sq.	0.046		0.078		0.055		0.095	

KI = knowledge(K) index; Z= z statistics. Significance ="* p<.1; ** p<.05; *** p<.01". Control variables for smallholder farmers include access to extension, farmer experience in years, land cultivated during the 2022 cropping season, age of household head, household size, gender of household head, educational qualification of household head. Control variables include trader experience in years, age of trader, gender of trader, educational qualification of household head and type of trader.

Table 10 extends our attitude results by showing the expanded knowledge components and their relationships to practices.

Table 10: Relationships between attitudes and knowledge sub-components, farmers and traders

Sample	Farmers				Traders			
Dep. Var. = attitudes index	(1)		(2)		(3)		(4)	
	Coeff	Z	Coeff	Z	Coeff	Z	Coeff	Z
Knowledge sub-components								
Production KI	0.232	(-1.23)	0.284	(-1.50)	0.357	(-1.01)	0.354	(-0.97)
Postharvest KI	0.108	(-0.67)	0.077	(-0.47)	0.617**	(-2.47)	0.628**	(-2.37)
Environmental KI	0.568**	(-2.42)	0.573**	(-2.43)	0.41	(-0.96)	0.378	(-0.85)
Knows aflatoxin	0.138	(-0.45)	0.112	(-0.35)	0.579	(-0.96)	0.436	(-0.70)
Seed duration	-0.018	(-0.06)	0.002	(-0.01)	-0.021	(-0.04)	0.001	(-0.00)
Controls	No		Yes		No		Yes	
N	444		444		160		160	
R-sq.	0.019		0.064		0.034		0.152	

KI = knowledge(K) index; Z= z statistics. Significance ="* p<.1; ** p<.05; *** p<.01". Control variables for smallholder farmers include access to extension, farmer experience in years, land cultivated during the 2022 cropping season, age of household head, household size, gender of household head, educational qualification of household head. Control variables include trader experience in years, age of trader, gender of trader, educational qualification of household head and type of trader.

For smallholder farmers, the environmental knowledge index has a strong positive association to attitudes (significant at the 5 percent level in with and without controls). Other components – production and postharvest indexes and knowledge of aflatoxin – have positive coefficients, but are insignificant. For traders, the postharvest knowledge index shows the largest and strongest relationship to attitude scores (significant at the 5 percent level with and without controls).

4. Conclusions and recommendations

Using primary data collected in Kasungu and Lilongwe ADDs, this paper makes an important contribution to the literature by analysing how aflatoxin knowledge is associated with the adoption of the practices of smallholder farmers or traders employed in minimising aflatoxin. The study further assesses the role of farmers' or traders' knowledge of aflatoxin on their attitudes towards aflatoxin. The study also analyses aflatoxin contamination levels in groundnut samples bought from smallholder farmers and traders, and how these compare to the aflatoxin thresholds in potential markets for groundnuts, both in developing countries, in the EU and USA. Furthermore, the study analyses patterns of smallholder farmer and trader knowledge, about aflatoxin, their attitudes towards aflatoxin and practices for minimising aflatoxins, and compares the differences between these two groups.

The results show that, in general, traders are more knowledgeable than farmers of aflatoxin and how to prevent mould formation in groundnuts. They have higher average knowledge scores each of the three sub-indexes as well: environmental factors, production, post-harvest. This result may not be surprising as traders work intimately with groundnuts – many of them all year long – as part of their central businesses, while farmers groundnut production may be only one component in a broad portfolio of livelihood activities. Interestingly, both farmers and traders show similar attitudes towards the safety (or risks) of consuming moulded groundnuts or animals fed moulded groundnuts. Less than 10 percent of each sample considered it safe for adults or children to consume moulded groundnuts directly.

Somewhat surprisingly, our results show that there are a few recommended practices to minimise aflatoxin contamination in groundnuts that the clear majority of smallholder farmers are already practicing. This includes proper shelling methods, and safe storage in a dry, covered location with nuts-in-shell. However, there are a number of production practices that could be improved to reduce the risks of mould formation including timely planting and harvesting.

Our regression analysis shows that higher knowledge is associated with better practices for smallholder farmers, but the relationship is insignificant for traders. The significant effect for farmers is driven by knowledge of production practices to minimise aflatoxin. The insignificant relationship for traders may not be surprising as they demonstrate high adoption of recommended practices overall and their practices relating to mould may be more driven by market conditions than individual knowledge.

Three key policy lessons emerge from the study. Firstly, strengthened extension services to disseminate information on farmer practices may improve adoption of aflatoxin-reducing practices. In particular, more training of agricultural extension officers may be warranted to ensure a more complete understanding of mould-mitigating practices pre and post-production – e.g., timely planting, crop rotation, weed and pest control, optimal planting densities, timely harvesting, thorough drying to reduce moisture content, recommended shelling practices that minimise damage of groundnuts, and storage in well-ventilated conditions – and more intentional efforts to distribute that information to farmers – e.g., through group trainings and farmer-to-farmer methods – should be encouraged. Second, considering knowledge does not drive trader practices, more research is needed to understand the market environments and contexts that may be affecting trader practices towards mould formation. This could include studies to identify how best to align local practices with international aflatoxin standards to enhance market access. Third, there is limited need for knowledge interventions around storage practices, for both smallholder farmers and traders as most respondents demonstrated the recommended practices in those categories.

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Appendices

Table A 1: Distribution of smallholder farmers traders interviewed by EPA and market name

Farmers			Traders		
EPA	Frequency	Percent	Market Name	Frequency	Percent
Bembeke	46	10.36	Kasungu	8	5.00
Chileka	50	11.26	Chatoloma	14	8.75
Chioshya	50	11.26	Mkanda	9	5.62
Chipala	50	11.26	Kapiri	5	3.12
Chulu	50	11.26	Kamwendo	1	0.62
Manjawira	49	11.04	Mchinji	8	5.00
Mkanda	49	11.04	Thete	6	3.75
Mvera	51	11.49	Chimbiya	5	3.12
Nthondo	49	11.04	Lizulu	1	0.62
			Tsangano Turn Off	27	16.88
			Kasungu other markets	37	23.12
			Mchinji other markets	24	15.00
			Dedza other markets	12	7.50
			Ntcheu other markets	3	1.88
Total	444	100	Total	160	100

Source: computed from survey data

Table A2: Smallholder farmer and trader practice scores

Farmer practices	Recommended practices (assigned value of 1)	Not recommended practices (assigned value of 0)
Post-harvest practices		
Main drying method [0,1]	Mandela cock	On plants, loose on ground with pods facing down
	On the plants with pods facing up	Stacking pole
	On plastic sheet	A-frame
		Pods only, on bare dirt ground
		On grass roof
		On iron roof
		On reed mat (Mphasa)

		On mesh sheet
Rained on groundnuts after harvest [0,1]	Did not rain on groundnuts after harvest	It rained on groundnuts after harvest
Threshing methods [0,1]	Threshed by hand (not by beating)	Threshed by hand (beating)
Wetting before shelling [0,1]	Did not wet groundnuts prior to shelling	Wetted groundnuts prior to shelling
Storage location [0,1]	In home	In covered but open-walled area
	In store house/room (walls and roof)	In woven crib (nkhokwe)
	In a covered area	
Storage method [0,1]	In bags unshelled	Open heap, shelled
	In sealed bags shelled or unshelled	Woven cribs (nkhokwe)
Production practices		
Timely planting [0,1]	Planted before January	Planted after January
Inter-row spacing [0,1]	Less than 50 cm	Greater than or equal to 50 cm
Weed control [0,1]	More than 1 complete weeding	Less than or equal to 1 weeding completed
Timely harvesting [0,1]	Harvested before May 15	Harvested after May 15
Overall Farmer Practice Score [0,10]	Sum of scores for each practice, indicating the overall adherence to good practices.	
Trader practices	Recommended practices (assigned value of 1)	Not recommended practices (assigned value of 0)
Storage methods [0,1]	Stored in bags (not open heaps)	Stored in open heaps
Location of storage [0,1]	In a storehouse/room	In covered area but open walls
Grading of groundnuts [0,1]	Graded/sorted groundnuts before selling	Not graded/sorted groundnuts before selling

Price based on quality [0,1]	Offer different prices to farmers for different quality groundnuts	Offer fixed price for all purchases
Overall Trader Practice Score [0,4]	Sum of scores for each practice, indicating the overall adherence to good practices.	

Table A3: Smallholder farmer and knowledge scores

Question	Question type	Accepted correct responses (assigned value of 1)	Incorrect responses (assigned value of 0)
Have you heard of aflatoxin? [0,1]	Yes/no	Yes	No
What is aflatoxin? [0,1]	Open-ended	A fungus	Don't know
		Rotten groundnuts	An insect pest
What are the major environmental factors which favour forming mould in your groundnuts (pre- or post-harvest)? [0,4]	Open-ended	Temperature	Don't know
		Humidity	
		Insect damage	
		Fungi	
What measures do you know for preventing moulding in groundnuts – during production (pre-harvest)? [0,7]	Open-ended	Early planting	Don't know
		Crop rotation	
		Healthy soils/fertilization	
		Using new & healthy seed	
		Apply pesticides to control pests/fungi	
		Harvest timing at maturity	
		Maintaining optimal plant densities	

Other factors being equal, which duration of groundnut seed is MOST likely to suffer from moulding risks? [0,1]	Select-One	Late maturity	Medium maturity (110 days)
			Early maturity (90 days)
			Don't know
Which measures do you know to prevent moulding in groundnuts – after harvest [0,7]	Open-ended	Rapid drying	Don't know
		Dry off the ground/soil	
		Avoiding ground contact at harvest	
		Hand sorting after harvest	
		Storing in a dry place, off the ground	
		Avoid storing in old contaminated bags	
		Appropriate shelling methods to reduce groundnut damage	
Overall knowledge score [0,21]		Sum of component indices	

Table A4: Smallholder farmer and trader attitude scores

Question	Question type	Assigned values	Description
Is it safe for adults to eat partially moulded groundnuts?	Open-ended, single select	0	Yes, very safe
		1	Yes, somewhat safe
		2	No, somewhat unsafe
		3	No, very unsafe
Is it safe for under-five aged children to eat	Open-ended, single select	0	Yes, very safe
		1	Yes, somewhat safe
		2	No, somewhat unsafe

partially moulded groundnuts?		3	No, very unsafe
Is it safe for adults to eat livestock products from animals fed moulded groundnut?	Open-ended, single select	0	Yes, very safe
		1	Yes, somewhat safe
		2	No, somewhat unsafe
		3	No, very unsafe
Is it safe for under-five aged children to eat livestock products from animals fed moulded groundnut?	Open-ended, single select	0	Yes, very safe
		1	Yes, somewhat safe
		2	No, somewhat unsafe
		3	No, very unsafe

Table A5: Summary of regression variables and expected directions of effect

Variable	Description	Expected direction
Practices Score	The dependent variable representing the overall aflatoxin minimization practices score.	n/a
Attitude scores	Explanatory variable representing the overall attitude score towards aflatoxin.	Increase in attitude score is expected to result in better practices.
Knowledge Scores	Explanatory variable representing the overall knowledge score about aflatoxin.	Increase in knowledge score is expected to result in better practices or attitudes.
Access to Extension	Control variable indicating whether a farmer has access to extension services.	Positive relationship— better access is expected to improve practices.
Age of household head or trader	Control variable representing the age of the household head or trader.	Uncertain— could be positive or negative
Household size	Control variable indicating the number of people in the household.	Uncertain— could be positive or negative

Sex of household head or trader	Control variable representing the gender of the farming household head or trader.	Uncertain— could be higher for males and lower for females
Level of Education	Control variable indicating the educational level of the farming household head or trader.	Positive relationship— higher education may lead to better practices.
Years Growing/trading groundnuts	Control variable indicating the number of years the farmer has been growing or the trader has been trading groundnuts.	Positive relationship— more experience may lead to better practices.