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Aflatoxin contamination: Knowledge disparities among agriculture extension officers, frontline health workers and small holder farming households in Malawi

Wanjiku N. Gichohi-Wainaina [a,*], Nelson Kumwenda [a], Rodah Zulu [b,1], Justice Munthali [b], Patrick Okori [a]

[a] *International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Lilongwe, Malawi*
[b] *Alliance of Bioversity International and CIAT, Lilongwe, Malawi*

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ABSTRACT

The aims of this study were to assess the state of knowledge and perceptions regarding aflatoxin contamination among frontline workers in direct contact with small holder farming households in Malawi as well as among the households themselves. The study first investigated and documented demographic profiles of agriculture extension workers (n = 22) and frontline health workers (n = 161) both from Ntchisi district and small holder farming households (n = 915) from Dedza, Balaka and Mzimba districts. Structured questionnaires were administered to document knowledge and perceptions. Majority of the respondents in Ntchisi were frontline nutrition and health workers as follows: care group promoters (31.7%), cluster leaders (51.9%) and health surveillance assistants (4.4%). Only 12% of the respondents were agriculture extension officers. Among frontline workers, using factor analyses, factors highly associated with the knowledge on domestic management of aflatoxin contamination and the impact of aflatoxin contamination on child linear growth and health in general were most prominent. Whereas, their knowledge of pre & post-harvest practices that pre-dispose crops to aflatoxin contamination and impact of aflatoxin contamination on trade and income losses was relatively low. On the other hand, among small holder farming households, lowest knowledge was related to occurrence of aflatoxin contamination pre and post-harvest. Highest knowledge was observed on issues around loss of income due to aflatoxin contamination. Across all districts over 50% of surveyed respondents reported that they perceived aflatoxin contamination severity as low. Majority of the households (>50%) did not perceive aflatoxin contamination as a problem that could be controlled.

This is the first study to investigate knowledge, attitudes, practices and perceptions on aflatoxin contamination among a combination of agriculture extension officers and frontline health workers in parallel with the households they usually are in contact with. The current investigation is crucial because it elucidates knowledge gaps in aflatoxin critical control across agriculture extension, health workers and the small holder farming households. This is especially crucial among agriculture extension workers and frontline health workers as they have direct contact with households and therefore serve as an important source of information that could influence behavior change.

1. Introduction

It is estimated that more than 25% of the world's food supply is contaminated by mycotoxins and up to 4.5 billion people are exposed (Smith et al., 2015; Williams et al., 2004). Mycotoxins are naturally occurring contaminants produced by the *Aspergillus, Penicillium* and *Fusarium* fungi and known to contaminate food supplies and farm animal feeds throughout the world (CAST, 2003, p. 2002; Wagacha & Muthomi, 2008; Wild & Gong, 2010). Even though approximately 400 mycotoxins have been discovered, aflatoxins and fumonisins are the most studied.

* Corresponding author.
E-mail addresses: w.gichohi@cgiar.org, wngichohi@gmail.com (W.N. Gichohi-Wainaina), N.Kumwenda@cgiar.org (N. Kumwenda), R.M.Zulu@cgiar.org (R. Zulu), J.Munthali@cgiar.org (J. Munthali), P.Okori@cgiar.org (P. Okori).
[1] Deceased.

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Aflatoxins are produced mainly by *Aspergillus* spp while fumonisins by *Fusarium* fungi (Feijo Correa, Orso, Bordin, Hara, & Luciano, 2018; Mutegi, Cotty, & Bandyopadhyay, 2018). *A. flavus* is ubiquitously found in soil and contaminates a variety of food crops including cereals, legumes, oilseeds, nuts, spices, coffee, tea, eggs, milk, and meat (CAST, 2003, p. 2002; Mutegi et al., 2018). The presence of aflatoxin metabolites in meat, milk and egg products are attributed to farm animals consuming contaminated feed (Kang'ethe & Lang'a, 2009; Nishimwe et al., 2019).

After establishing these food sources as a host, *A. flavus* produces aflatoxins, including AFB1, which then contaminates the food supply. Fungal growth can occur on the food at the pre or post-harvest stage, making it problematic to control contamination. Additionally, high temperatures and humidity encourage fungal growth so countries that have these environmental conditions, often experience higher contamination (Rushing & Selim, 2019).

Exposure to aflatoxin has different effects on morbidity and mortality depending on whether exposure is short term (acute) or chronic. It can result in growth retardation, immune-suppression, liver damage or at worst, death (Khlangwiset, Shephard, & Wu, 2011; Probst, Njapau, & Cotty, 2007; Shivachandra, Sah, Singh, Kataria, & Manimaran, 2003). In terms of income, aflatoxins are a major constraint of accessing lucrative export markets leading to loss of income for farmers.

Aflatoxin contamination can be mitigated at critical points pre or post-harvest by following Good Agricultural Practices (GAP) and Good Storage Practices (GSP). As part of ensuring GAPs' and GSPs' are practiced, small holder farmers require information. In Malawi, agriculture extension workers as well as frontline nutrition and health workers present important sources of information and thus change agents (Group, 2009; IFPRI, 2020). To this end, a questionnaire was designed to assess the knowledge and perceptions of agriculture extension officers and frontline health workers as well as small holder farming households on aflatoxin contamination.

Questions included were in 6 broad categories based on:

1. Knowledge on pre and post-harvest agricultural practices that predispose crops to possible aflatoxin contamination
2. Aflatoxin laden grain as animal feed and aflatoxin exposed animal products as human food Knowledge on impacts of aflatoxin exposure on children's linear growth and health
3 Knowledge of impacts of aflatoxin exposure on income
4 Knowledge on domestic methods to mitigate aflatoxin
5 Perceptions of the gravity of the aflatoxin contamination problem

This survey presents the state of knowledge, attitudes and practices regarding aflatoxin contamination among potential disseminators of the knowledge (agriculture extension and frontline health workers) vis-à-vis their recipients (small holder farming households).

2. Methodology

2.1. Study site

Data was collected from four districts-Ntchisi, Balaka, Dedza and Mzimba.

Ntchisi lies in the mid elevation and highland zone of the central region of Malawi. The mean annual temperature varies between 22 °C in low altitude areas and 18 °C in high altitude areas. Annual rainfall ranges from 900 mm to 1,500 mm (Adam Andreski, 2005).

Balaka district is located in Southern Malawi in the lake shore, middle and upper shire agro ecological zone. The district receives an annual rainfall level of between 700 mm and 1100 mm. The minimum and maximum temperatures are 14 and 32 °C, respectively (Mango, 2017).

Dedza district is located in the Central Region of Malawi and lies in the mid elevation and highland zone of the central region of Malawi. The district receives mean annual rainfall fluctuating between 800 mm and 1200 mm (Munthali, 2020). The average annual temperature is 15.5 °C. Mzimba district is located in northern Malawi, and lies in the mid elevation agro ecological zone. The average annual temperature is 20.1 °C and annual rainfall 915 mm (Climate-Data.Org; Matumba et al., 2015).

All the selected districts have different vulnerabilities to aflatoxin contamination due to their rainfall patterns and/or average temperatures (E.S.Monyo, 2012).

2.2. Sampling methodology

In Ntchisi, the two EPAs' (Chipuka and Kalira) were purposively selected as part of the MSIDP phase II project zone of influence areas. Extension planning areas are one of the government agriculture extension system administrative hierarchy (Simpson BM,and Malindi, 2012). These two EPAs' cultivate considerable amounts of groundnut.

The selected households in Balaka, Dedza and Mzimba were part of a larger case control nutrition study within the Malawi Seed Industry Development Project phase II (MSIDP Phase II). The nutrition study was designed to investigate the drivers of stunting in the three distinct agro ecological zones of Malawi.

The 2008 Malawi Population and Housing census sampling frame was used to select the study population in Balaka, Dedza and Mzimba. Since the interest for the original study was the farming households, the rural areas within each of the three selected districts formed the main sampling stratum. Within each district, a specific traditional authority (TA) was purposively selected for the study based on production of crops of interest within the larger study. The traditional authority leadership is administratively charged with leading development initiatives within the designated area.

Finally, 153 cases (households with stunted children) and a similar number of matched controls (1:1) per TA were randomly selected from an eligible list of screened households. Matching was based on age, sex and location (residing in the same TA).

2.3. Ethical approvals and consent

For the Ntchisi study, written informed consent was obtained prior to administering the questionnaire.

For the respondents from Balaka, Dedza and Mzimba, ethical approval for the case control study was obtained from the National Health and Science Research Committee (Approval Number March 17, 1745). In addition approvals from administrative officials, district medical officers as well as traditional authorities was obtained. Prior to administering the questionnaire, all respondents' provided written informed consent.

2.4. Questionnaire and data collection

A questionnaire was designed to capture socio-economic characteristics of the respondents and knowledge, attitudes and practices as well as perceptions on aflatoxin contamination. The questionnaire administered in Ntchisi had 21 items on aflatoxin knowledge, attitudes and practices while that administered in Balaka, Dedza and Mimba South had 13 items. For the questions on knowledge, respondents had to either state they: don't know, disagree or agree. On perceptions, 2 questions were asked:

1. How serious do you think the aflatoxin contamination problem in your area is? The responses were either don't know, not very serious, somehow serious or very serious
2. Do you think aflatoxin in maize and groundnut can be controlled? Response could be yes or no

A question on sources of information on aflatoxin contamination was also included.

All questionnaires were administered by enumerators who either had a BSC degree or had previous experience administering questionnaires. Prior to questionnaire administration, enumerators were trained and their competence in questionnaire administration skills deemed satisfactory based on a pretesting exercise. The interviews were conducted in the local languages in July 2018 (Balaka, Dedza and Mzimba) and April 2019 in Ntchisi. Questionnaires were checked both by the survey team supervisors and principle investigator prior to data analyses.

2.5. Statistical analyses

Descriptive statistics were used to summarize the data. All responses were recoded prior to data analyses. Since the questionnaire had statements in which respondents could either respond they don't know, disagree or agree, the correct responses were always coded as 1 and the wrong responses and don't know as 0.

A KAP score was computed as sum of all responses to the questions. The total KAP Score for Ntchisi could range between 0 and 21 where 0 indicated no knowledge and 1 indicates full knowledge. On the other hand, for Balaka, Dedza, Mzimba could range from 0 indicating no knowledge and 13 indicating full knowledge. Next, the Bartlett sphericity test was used to ascertain if the samples were from populations with equal variances. In order to determine the underlying structure for W_i, factor analysis was then applied to the KAP score data. Additionally, the Kaiser-Meyer-Olkin measure of sampling adequacy was also utilized to assess sample sizes for adequacy for conducting factor analysis (HF, 1958b). All statistical tests were conducted using Stata 16 statistical software (StataCorp, 2019). P values for tests of statistical significance was set at 0.05.

3. Results

3.1. General characteristics of the study population

3.1.1. Ntchisi

There were 182 respondents from Ntchisi with female respondents consisting of 58.5% of the population. Majority of the Ntchisi respondents had primary (47.5%) or secondary education (42.1%). Additionally, majority of the respondents in Ntchisi were frontline nutrition and health workers as follows: care group promoters (31.7%), cluster leaders (51.9%) and health surveillance assistants (4.4%). Only 12% of the respondents were agriculture extension officers (Table 1).

3.2. Balaka, Mzimba and Dedza

A total of 915 respondents from small holder farming households with an average age of 28.3, 30.0 and 28.9 years from Balaka Mzimba and Dedza respectively were interviewed. Of the respondents, 51.8% (Balaka), 49.3% (Dedza) and 47.4% (Mzimba) were female. Majority of the households reported their main livelihood source as own farm production-45.5% in Balaka, 42.4% in Dedza and 61.7% in Mzimba. In terms of level of education, most households reported their highest level of education as primary school education with 73.5%, 79.7% and 83.2% in Balaka, Dedza and Mzimba. In regards to asset ownership, we focused on assets that could prove vital in information dissemination to small holder farming households. Mobile phone ownership across Balaka (52.2%), Mzimba (31.6%) and Dedza (58.2%) districts was wide compared to radio or television (Table 1).

3.3. Factor analysis

3.3.1. Ntchisi

The Bartlet's sphericity test was highly significant ($P = 0.000$), thus indicating that the variables were inter-correlated. In addition, the Kaiser-Meyer-Olkin measure of sampling adequacy was 0.75, showing that factor analysis could be used. Next, factor analysis was used to reduce dimensionality in the data, and factors were chosen based on eigenvalues of ≥ 1 (HF, 1958a), a scree plot (not shown), and factor loadings of ≥ 0.40. As a result, three factors were extracted accounting for 85% of the variance within the data (Table 2). These factors are highly associated with the knowledge on domestic management of aflatoxin contamination through cooking or washing grain. Knowledge of the impact of aflatoxin contamination on child linear growth and health in general was also relatively high. Whereas, their knowledge of pre & post-harvest practices that pre-dispose crops to aflatoxin contamination was relatively low, with low loadings regarding the effect of sprinkling water to ease shelling or increase weight of produce on increasing chances of mycotoxin contamination. Knowledge on impact of aflatoxin contamination on trade and income losses was also

Table 1
Frontline agriculture and health workers and small holder farmer characteristics.

Variable	*n*	Ntchisi	*n*	Balaka	*n*	Dedza	*n*	Mzimba
Sex, n, (% female)	107	58.5		51.8		49.3		47.4
Age, n, (years)	182	35.6 (34.3, 36.8)	307	28.3 (26.6, 29.9)	300	30.0 (28.2, 31.7)	308	28.9 (27.3, 30.6)
Designation								
Agricultural Extension Development Officer (AEDO)	22	12	–	–	–	–	–	–
Caregroup Promoter	58	31.7	–	–	–	–	–	–
Cluster leader	95	51.9	–	–	–	–	–	–
Health Surveillance Assistant (HAS)	8	4.4	–	–	–	–	–	–
Source of livelihood								
Agriculture production on own farm, n (%)	–	–	181	45.5		42.4		61.7
Livestock sales, n (%)	–	–	2	0.5		18.7		13.7
Formal employment, n (%)	–	–	13	3.3		1.7		2.1
Remittances, n (%)	–	–	5	1.3		0.5		0.3
Others, n (%)	–	–	197	49.4		36.7		22.2
Level of Education, n, (%)								
No education	–	–		8.3		13.1		5.2
Primary	87	47.5		73.5		79.7		83.2
Secondary	77	42.1		17.9		6.8		10.9
Tertiary	19	10.4		0.3		0.3		0.7
Asset ownership, n (%)								
Mobile Phone	–	–	163	52.2	99	31.6	185	58.2
TV	–	–	17	5.5	7	2.2	19	6.0
Radio	–	–	86	27.6	63	20.1	89	28.0

Blanks represent that no data was collected on the specific variable.

Table 2
Varimax rotated factor structure of the twenty one items of knowledge on mould toxin among Ntchisi district frontline health and agriculture extension workers.

Variable	Ntchisi
N	182
Pre & post-harvest practices that pre-dispose crops to aflatoxin contamination	
Aflatoxin contamination can occur while the crop is in field	0.45
Broken and bruised crops increase the chance of aflatoxin contamination	–
Aflatoxin contamination can occur during harvest	0.50
Aflatoxin contamination can occur during drying the crop produce	0.51
Aflatoxin contamination can occur during storage of your crop produce	–
Aflatoxin contamination can occur if the storage place is wet	–
Aflatoxin contamination can occur if you sprinkle water during shelling	0.41
Aflatoxin contamination can occur if you sprinkle water to increase weight of crop produce for selling	0.41
Aflatoxin contamination can occur during pest infestation	0.54
Aflatoxin laden grain as animal feed and aflatoxin exposed animal products as human food	
Aflatoxins can be transferred in milk and dairy products	0.63
Aflatoxin contaminated grains should not be fed to livestock	0.47
If people eat eggs, milk or milk from animals which are fed on mouldy grain, do the people get any health effects from the mould	0.60
Aflatoxin contamination and children linear growth & health	
Aflatoxins can be transferred into breast milk	0.65
Aflatoxin can affect the growth and development of children	0.69
Aflatoxin can affect immunity	0.70
Aflatoxin can cause liver cancer in humans	0.66
Aflatoxin contamination and income	
Farmers/traders can lose income due to aflatoxin problem	0.41
Aflatoxin-contaminated grain cannot be exported to some countries	0.45
Aflatoxin contamination and domestic management	
Washing mouldy grain eliminates any potential health effects of mould	0.78
Cooking mouldy grain eliminates any potential health effects of mould	0.79
Aflatoxin contamination can reduce if you sort/grade your crop produce	–

Blanks represent |loading| < 0.40.

relatively low.

3.4. Balaka, Dedza and Mzimba

The Bartlets sphericity test was also highly significant (P = 0.000), thereby indicating that the variables were inter-correlated. In addition, the Kaiser-Meyer-Olkin measure of sampling adequacy for the combined data from Balaka, Mzimba and Dedza was 0.87, showing that factor analysis could be used. Similarly, the Kaiser-Meyer-Olkin measure for responses from Balaka, Dedza and Mzimba separately were 0.84, 0.86 and 0.84 respectively, also indicating sample size was adequate for factor analyses for the individual districts (Table 3). After this, Factor analysis was then used to reduce dimensionality in the data, and the factors were chosen based on eigenvalues of ≥1, scree plots, and factor loadings of ≥0.40 (HF, 1958b). When data was combined, two factors were extracted explaining 92% of the variance in the data. These factors are highly associated with the effect of aflatoxin contamination on loss of income based on the high factor loadings. While the knowledge of occurrence of aflatoxin contamination in the field and during drying of produce was low indicated by their factor loadings (0.41). Similarly, when factor analyses was performed by district two factors were extracted explaining 86%, 90% and 88% of the variance in the data. As in the combined data, the extracted factors are highly associated with pre & post-harvest practices that pre-dispose crops to aflatoxin contamination. Once again lowest factor loadings were related to knowledge on the point of occurrence of aflatoxin contamination. In Balaka and Dedza specifically there was a low factor loading for knowledge of aflatoxin occurrence during harvest (0.45 and 0.41 respectively) while in Mzimba it was on aflatoxin occurrence in the field (0.42). Highest factor loadings in all districts were observed on issues around loss of income due to aflatoxin contamination of produce.

Table 3
Varimax rotated factor structure of the thirteen items of knowledge on mould toxin among smallholder farmers in Balaka, Dedza and Mzimba districts.

Variable	Balaka	Dedza	Mzimba	All
n	96	122	247	465
Pre & post-harvest practices that pre-dispose crops to aflatoxin contamination				
Aflatoxin contamination can occur while the crop is in field	0.50	0.46	0.42	0.41
Aflatoxin contamination can occur during harvest	0.45	0.41	0.67	0.62
Aflatoxin contamination can occur during drying the crop produce	0.49	0.46	0.54	0.41
Aflatoxin contamination can occur during storage of your crop produce	0.57	0.68	0.57	0.60
Aflatoxin contamination can occur if the storage place is wet	0.69	0.70	0.73	0.71
Aflatoxin contamination can occur if you sprinkle water during shelling	0.71	0.77	0.77	0.75
Aflatoxin contamination can occur if you sprinkle water to increase weight of crop produce for selling	0.78	0.75	0.77	0.76
Aflatoxin laden grain as animal feed and aflatoxin exposed animal products as human food				
Aflatoxin contaminated grains should not be fed to livestock	0.70	0.65	0.63	0.65
Aflatoxin contamination and children linear growth & health				
Aflatoxin can affect the growth and development of children	0.74	0.71	0.69	0.71
Aflatoxin can affect immunity	0.75	0.74	0.69	0.72
Aflatoxin contamination and income				
Farmers/traders can lose income due to aflatoxin problem	0.85	0.77	0.79	0.80
Aflatoxin-contaminated grain cannot be exported to some countries	0.85	0.78	0.77	0.79
Aflatoxin contamination and domestic management				
Aflatoxin contamination can reduce if you sort/grade your crop produce	0.58	0.69	0.58	0.61

Blanks represent |loading| < 0.40.

3.5. Knowledge, attitudes and practices score on aflatoxin contamination

The average KAP score in Ntchisi was 37.8 out of a possible 42. The average KAP score among the small holder farmer households was 20.9, 21.5 and 21.4 across Balaka, Dedza and Mzimba out of a possible 26 (Table 4). These differences were not significantly different across districts (P = 0.74). When comparisons between groups were made across the same districts, stratified by age, sex and education level, the only significant differences in KAP score was observed for education level (P = 0.02). Across all districts, the KAP score increased as education level increased with respondents with a tertiary education (certificate and diploma) having the highest scores and those with no education the lowest scores. No differences between groups were observed in Ntchisi.

3.6. Sources of information on aflatoxin contamination among small holder farming households

We then sought to understand the sources of information on aflatoxin contamination among small holder farming households surveyed in Balaka, Mzimba and Dedza. Majority of the respondents reported to have received information on aflatoxin contamination as inherited knowledge, from agriculture extension workers, radio/TV and from friends (Fig. 1). Inherited knowledge in this case meant practices or knowledge that are perpetuated within the household from one generation to the next. None reported to have received information from frontline health workers. The category others referred to sources of information such as agricultural meetings or agriculture fairs and from Non-Governmental Organizations (NGOs'). Within districts, importance of sources of information varied (Fig. 1). For example, in Balaka district, 28% of respondents responded to having received information from

Table 4
Knowledge, Attitudes and Practices score and differences in score between age, sex and education level.

Variables	*n*	Balaka	*n*	Dedza	*n*	Mzimba	P*	*n*	Ntchisi	P$
KAP Score, mean (Std. Dev)	96	20.9 (4.3)	122	21.5 (4.0)	247	21.4 (3.9)	0.74	182	37.8 (3.6)	–
Age										
≤39 years	71	21.1 (4.4)	70	21.2 (4.1)	183	21.5 (3.8)	0.69	121	37.9 (3.5)	0.74
>39 years	25	20.2 (4.0)	52	21.8 (3.9)	64	21.2 (4.1)		62	37.7 (4.0)	
Sex										
Male	41	22.1 (3.8)	64	21.4 (4.1)	120	20.8 (3.9)	0.13	107	37.7 (4.1)	0.52
Female	53	20.0 (4.5)	53	21.6 (4.0)	118	21.9 (3.8)		75	38.1 (2.9)	
Education Level										
None	6	18.2 (4.7)	18	20.6 (4.5)	9	20.7 (3.6)	0.02	–	–	0.06
Adult literacy	2	15.5 (3.5)	1	24	1	19		–	–	
Primary	67	21.0 (4.2)	83	21.4 (4.0)	199	21.2 (3.9)		87	37.5 (4.3)	
Secondary	18	22.2 (4.3)	12	22.8 (3.4)	25	22.2 (3.7)		77	37.8 (3.0)	
Tertiary (Diploma and Certificate)	-	-	1	25	2	25.5 (0.7)		18	39.7 (1.6)	

P*; Differences in means between groups across the Balaka, Dedza and Mzimba, P$; Differences in means between groups in Ntchisi district only, P values < 0.05 are significant.

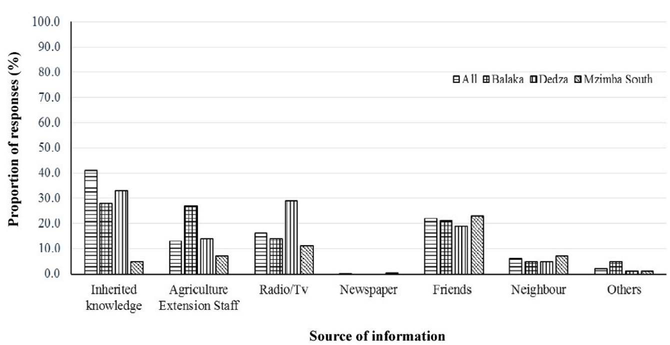

Fig. 1. Sources of information on aflatoxin contamination in a sample of small holder farming households in Balaka, Dedza and Mzimba.

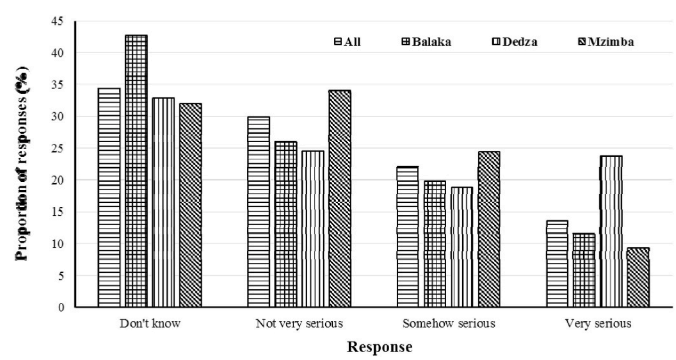

Fig. 2. Perceptions from a sample of small holder farmer households in Balaka, Mzimba and Dedza on the severity of aflatoxin contamination in their district.

agriculture extension officers compared to 14% and 7% in Dedza and Mzimba respectively. On the other hand, 29% of respondents in Dedza had received information on aflatoxin contamination from radio compared to 14% in Balaka and 11% in Mzimba.

3.7. Perceptions of aflatoxin contamination

Two questions investigating perceptions of the aflatoxin problem were then asked:

1. How serious do you think the aflatoxin contamination problem in your area is?
2. Do you think aflatoxin in maize and groundnut can be controlled?

Across all districts over 50% of surveyed respondents reported that they did not have any perception (I don't know) of the severity of the aflatoxin problem or perceived it's severity as low (Fig. 2). On the other hand, in terms of the perception on whether aflatoxin contamination in maize and groundnut could be controlled, only 49% of respondents in Balaka perceived the problem to be one that could be controlled as opposed to 40% and 46% of respondents in Dedza and Mzimba respectively (Fig. 3).

4. Discussion

This survey was conducted to assess respondents' knowledge, attitudes, and practices on aflatoxin contamination across 4 districts in Malawi. All districts selected for the survey represent the three distinct agro ecological zones of Malawi. Our data suggests that among agriculture extension officers and frontline health workers, knowledge on domestic management of aflatoxin contamination and that on impact of

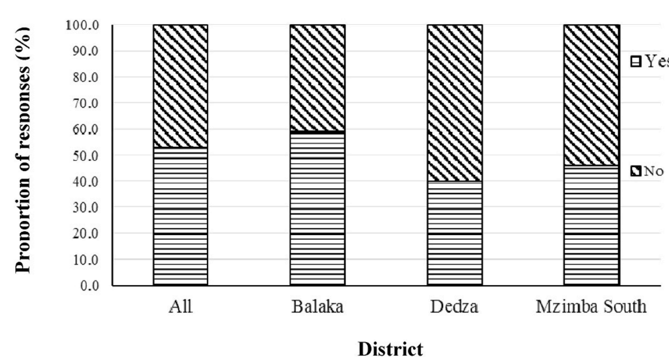

Fig. 3. Perceptions from a sample of small holder farmer households in Balaka, Mzimba and Dedza on whether aflatoxin contamination in groundnut and maize can be controlled

aflatoxin contamination on child linear growth and health in general was relatively high. On the other hand, among small holder farmers surveyed, highest knowledge was associated with the effect of aflatoxin contamination on loss of income. Farmers' knowledge of the impact of aflatoxin contamination on growth and development of children and on immunity was also relatively high.

This is the first study to investigate knowledge, attitudes and practices survey on aflatoxin contamination among a combination of agriculture extension officers and frontline health workers. The current investigation is crucial because the role of aflatoxin mitigation requires a concerted effort since it is at the interface of agriculture, trade and health. Agriculture extension workers and frontline health workers have direct contact with households and therefore serve as an important source of information and may therefore influence behavior change.

Similar findings on lack of knowledge on pre and post-harvest aflatoxin mitigation approaches have been observed among small holder households in Malawi (Anitha et al., 2019). This observation is of concern since it is likely that the lack of knowledge may contribute to high aflatoxin contamination. Indeed various studies in Malawi have observed high aflatoxin exposure in the population either through assessing food samples (Matumba et al., 2015; Mwalwayo & Thole, 2016; Njoroge, 2018) or biological samples (Seetha et al., 2018). Creating pervasive awareness from production to consumption about mitigating aflatoxin exposure and its effects, explicitly in at-risk communities (e.g. targeted agricultural, nutritional, and health education), is vital for management. Interestingly we observed in our study that over 50% of the small holder households were not aware of aflatoxin contamination as a serious problem or did not perceive the problem as serious. Additionally, approximately 60% did not perceive aflatoxin contamination in groundnut or maize could be controlled. This finding further buttresses the evidence that innovative strategies are required to mitigate aflatoxin contamination. Such strategies should take into account that, often food consumed from smallholder and subsistence farming as well as informal markets is rarely subject to regulatory assessment for aflatoxin contamination. In the case of rural populations such as those assessed here, it is also critical to investigate what sources of information are accessible and trusted to avoid panic. Well-designed information dissemination campaigns would serve as the foundation for initiating and sustaining behavior changes that mitigate aflatoxin contamination. Most households reported having received information from other individuals-agriculture extension workers, neighbors, and friends. Households also reported to have a high mobile phone ownership. The use of technology to have widespread information dissemination would thus be considered especially in communities that have appreciable literacy. Mobile phones are also useful as they now serve as a source of receiving radio programs as well.

In terms of agriculture extension services, previous studies demonstrate that many agricultural extension services do not have a specific agenda which includes aflatoxins, mycotoxins, food safety, or good agricultural practices on mitigation in their messaging (Stepman, 2018). A deliberate effort to include training on aflatoxin mitigation targeted to agriculture extension workers should be made. Such a training should specifically focus on aflatoxin mitigation using the Hazard Analyses and Critical Control Points (HACCP) approach. In particular, training on hazard analyses and critical control points should include: identification of mycotoxin hazards, identification of steps in the commodity value chain where mycotoxin contamination may occur and possible control measures at each critical point. This would enable agriculture extension workers effectively deliver information and training to farmers.

We observe that none of the small holder households reported frontline health workers as a source of information. Though the frontline health workers interviewed were from a different district, we observe a disparity in the most important knowledge aspects between agriculture extension officers, frontline health workers and small holder farming households. The former groups' knowledge (which mostly consisted of frontline health workers) was centered around domestic mitigation of aflatoxin contamination while that of small holder farmers was focused around aflatoxin and its impact on loss of income.

The solutions to mitigate aflatoxin contamination require integrated ways of working together between different sectors. Our findings indicates a greater need to ensure that frontline health workers are empowered to impart knowledge on aflatoxin exposure and impacts on health. In Malawi where the care group model is employed, involving care groups could prove to be effective in mitigating aflatoxin exposure. The Care Group model saturates villages with health information and support services through networks of community volunteers, usually comprised solely of women. It also targets women of reproductive age and children up to 2 years to whom exposure to aflatoxin has detrimental effects (Group, 2009). Though the care group leaders teach mothers on various infant feeding and care practices, the curriculum does not include food safety. Involving community health workers (CHWs') is crucial in ensuring success of an aflatoxin mitigation strategy. These CHWs' have formerly been effective in improving coverage of vital health care maternal and child intervention leading to improvements in mortality in various settings. Similar successes could be duplicated in relation to aflatoxin mitigation further contributing to improved health.

Ultimately, behavior change would only be achieved if messaging was developed together between CHWs' and agriculture extension to ensure both health, agriculture and income are embodied in the messaging.

With regard to the level of education we found that those with the lowest education had the lowest knowledge. It is possible that those with higher knowledge have access to multiple sources of information compared to those with none. However this is not known with certainty.

We understand that the survey among agriculture extension and community health workers is small and utilizes purposively selected respondents in a different district from that of the small holder farmers. It is therefore prone to all the limitations of purposive sampling but also questions on generalizability of findings to all agriculture extension and frontline health workers.

However, this study findings remain crucial in designing future aflatoxin mitigation strategies. It is likely similar findings would be observed among other cohorts of agriculture extension and frontline health workers as they are all trained utilizing similar curriculum cascaded from respective line ministries. Moreover, our findings provide significant new information on knowledge among a crucial group in direct contact with households. These observations are useful in planning interventions designed to create awareness and reduce aflatoxin contamination especially among small holder farming households.

With regards to the generalizability of the observations among the small holder farming households, these findings likely reflect the status of knowledge among small holder farmers in Malawi. This is because households were randomly selected, represent varying regions of production and education levels and replicate previous observations (Anitha et al., 2019).

Interventions to address aflatoxin contamination are urgently needed considering the high consumption of aflatoxin prone grain in Malawi (Joy EJM, 2015; Joy et al., 2019) and the subsequent detrimental health effects of chronic dietary intake of low to moderate levels of aflatoxin (Egal et al., 2005; Gong et al., 2003; Kowalska, Walkiewicz, Kozieł, & Muc-Wierzgoń, 2017; Smith, Prendergast, Turner, Humphrey, & Stoltzfus, 2017). These interventions must be innovative and multisectoral to ensure sustained behavior change. Farmers can mitigate aflatoxin contamination in crops pre and post-harvest by adopting various practices (Bandyopadhyay, 2016; Njoroge, 2018; Waliyar, 2014). However, effective implementation of HACCP requires education and awareness about the impacts of mycotoxins among other approaches (Strosnider et al., 2006).

It should also be noted that increasing knowledge solely may not significantly change farmers' attitudes towards aflatoxin mitigation or indeed their practices. Regulations on the other hand are likely to have a limited effect on the foods consumed on the farm or sold in informal markets, where the poorest farmers sell their produce and the poorest consumers buy their products. To ensure adoption of mitigation strategies approaches that take into account a financial incentive for grain that meets standards must be effected. However focusing on a financial incentive only especially for export may be detrimental. For example, countries that attempt to export aflatoxin laden grain abroad sometimes find their export markets severely threatened by stringent aflatoxin standards, resulting in probable countervailing risks of exporting the best foods and retaining the worst domestically (Wu, 2004). Sometimes economic yield losses may be up to 100% if the aflatoxin levels are beyond the stipulated levels in some cases (Misihairabgwi & Ezekiel, 2019, pp. 43–58). In such a case, households may choose to retain the grain for own consumption or sale in local unregulated markets. Alternative end use of contaminated grain would thus be an expedient alternative to ensure aflatoxin laden grain is not retained within the food system.

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CRediT authorship contribution statement

Wanjiku N. Gichohi-Wainaina: Project administration, Conceptualization, Methodology, Formal analysis, Visualization, Writing - original draft, Writing - review & editing. **Nelson Kumwenda:** Project administration, Writing - original draft. **Rodah Zulu:** Project administration. **Justice Munthali:** Project administration. **Patrick Okori:** Supervision.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.foodcont.2020.107672.

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