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Knowledge, attitude, and practices concerning presence of molds in foods among members of the general public in Malawi

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Abstract This study assessed knowledge, attitude, and practices (KAP) of the public in Malawi on issues related to molds in foodstuffs. A survey involving structured questionnaire was conducted with 805 respondents from seven districts of Malawi. Descriptive statistics, *t* tests, and analyses of variance were calculated. A majority of respondents recognized that molds were dangerous to human health (88 %); however, about 50 % of respondents were not informed that mold toxins are thermally stable and that they are not destroyable by normal cooking processes. About 33 % of the respondents asserted that they buy moldy maize, while approximately 20 % of respondents reported that they consume moldy fruits having discarded moldy fraction. There were significant differences in knowledge scores among different demographic groups. Females had significantly ($p < 0.05$) lower knowledge scores on issues related to molds in foods. Additionally, the respondent's location had a significant effect. However, respondent's education had subtle effect on knowledge score and the overall population's knowledge score was generally low (3.55 ± 1.32 score out of 9). Results of the study underline the need to raise public's knowledge about health risks associated with spoilage molds in food and prevention and management options.

Keywords Mold · Food · Knowledge · Attitude · Practice · Malawi

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Introduction

Molds are ubiquitous in nature and grow almost anywhere, indoors and outdoors (Sandra et al 1996). Some genera of fungi play a substantial role in spoilage of foodstuffs, and during various growth stages may generate different low molecular weight secondary toxic metabolites called mycotoxins. The occurrence of mycotoxins is of public concern due to their association with a wide array of adverse health effects including carcinogenicity, mutagenicity, teratogenicity, oestrogenicy, neurotoxicity, or death based on the type, dose, sex, health, age, and nutritional status of the exposed being (Fung and Clark 2004; Hussein and Brasel 2001; Lewis et al. 2005; Peraica et al. 1999; Reddy et al. 2010). Of particular interest is the capacity of most mycotoxins to suppress immune function and decrease resistance to infectious diseases, reactivate chronic infections, and decrease vaccine and drug efficacy (Berek et al. 2001; Corrier 1991; Jiang et al. 2005; Oswald et al. 2005; Pestka et al. 1987; Sharma 1993). Specifically, evidence indicates that aflatoxins (the most studied metabolites) increase the rate of progression from HIV infection to AIDS (Jolly et al. 2013; Jolly 2014).

To date, over 400 mycotoxins have been elucidated (Hussein and Brasel 2001; Bennett and Klich 2003). The development of liquid chromatography-mass spectrometry (LC-

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MS) methods for the simultaneous detection and quantification of a broad spectrum of mycotoxins has facilitated the screening of a wide array of less well-known mycotoxins (Malachova et al. 2014; Sulyok et al. 2006, 2007, 2010). In Malawi, a recent analysis of maize (the main staple) from various agricultural zones detected between 5 and 41 metabolites in individual samples most of which are just emerging toxins whose toxicokinetics are still largely unexplored (Matumba et al. 2014). Since toxicological synergism exists among the mycotoxins, the high co-occurrence of the toxins highlighted above require attention (Pedrosa and Borutova 2011; Speijers and Speijers 2004). Several strategies to minimize mycotoxin poisoning exist today. These involve pre-harvest control (e.g., use of pest and disease-resistant plants, crop rotation, insect control…) and post-harvest control (e.g. drying, sorting, and removal of moldy foodstuff…) (Bruns 2003; Chulze 2010; Matumba et al. 2015c). In most cases, the presence of molds on foodstuffs indicates a high probability of a presence of at least one toxin. Considering that the majority of the population in Malawi are subsistent farmers who have no access to mycotoxin testing, the presence of molds in foods could be practically used as a proxy for mycotoxin contamination and potentially reduce dietary exposure among the population. However, effective implementation of as the above strategies by the general public requires education and awareness about dangers of mycotoxins, and behavioral changes in pre- and post-harvest handling (Strosnider et al. 2006).

In this context, the purpose of this study was to examine the knowledge, attitudes, and practices (KAP) of the Malawian general public towards the presence of molds, as an indicator of mycotoxins in their foodstuffs, in order to inform development of a comprehensive national information, education, and communication (IEC) program aimed at mycotoxin prevention and management. To the best of our knowledge, this is the first KAP study on molds in foodstuffs conducted in Africa. Previous studies have focused on aflatoxins and to a less extent mycotoxins, in general (Ezekiel et al. 2013; Ilesanmi and Ilesanmi 2011; James et al. 2007; Jolly et al. 2009; Kaaya et al. 2006; Mboya and Kolanisi 2014).

Methodology

Data collection

The demographics of Malawi encompasses about 16 million people of diverse origins, cultures, languages, and religions of which ~80 % live in rural areas (Malawi National Statistical Office, MNSO 2012). In order to draw a representative sample of the population, a multi-stage sampling technique was used to obtain a total of 805 respondents. In the first stage, seven districts out of 28, namely Mzimba, Mchinji, Mangochi, Blantyre, Ntcheu, Thyolo, and Chikwawa, were purposely included into the survey based on geographical and socio-economical setting. Within each selected district, one township and two agricultural extension planning areas (EPAs) were randomly selected. An EPA is an agricultural development division of a district comprising of 15,000–40,000 farmer households. Approximately 40 households per EPA were systematically included into the study by firstly skipping a village within an EPA and secondly selecting three houses within each selected village. In case of townships, the sampling scheme involved selecting every sixth household along streets until roughly 40 houses were realized.

A questionnaire was designed to capture socio-economic characteristics of the public, perceptions, awareness, and knowledge of molds, and practices they applied to control and manage the problem. The questionnaire was administered by a team of ten. Seven (7) of the administrators had at least a minimum of first degree and three (3) had an undergraduate diploma but with extensive mycotoxin experience (working in a government mycotoxin laboratory). All these administrators were first trained and their competence questionnaire administration skills deemed satisfactory based on pretesting exercise. Before administering the questionnaire, verbal consent was obtained using a standardized consent script. The interviews were conducted in a local language, in English, or a combination of the two languages, as appropriate from mid-February to mid-March 2015. The completed questionnaires were manually checked by the principal investigator before they were coded into Stata 13.1 statistical software (StataCorp LP. STATA 13.1 SE 2015).

Statistical data analysis

Descriptive statistics were used to summarize the data. Eight important variables capturing respondents' knowledge of: (i) environmental factors that favor mold proliferation, (ii) thermal stability of the mold toxins, and (iii) health effects associated with consumption of contaminated food stuffs were selected from the data. Given $k=1$, ….,8 variables, a KAP score was computed as sum of all positive ($Yes=1$) responses to the questions i.e. $\mathrm{KAP_{SCORE}} = w_i = \sum_1^k x_1$ where w_i is the final score. In order to determine the underlying structure for w_i, factor analysis was applied to the score data (Smith 2002; Kessler 2006; Liu et al. 2003). Since it was possible to obtain a zero score if the respondent had absolutely no knowledge about toxins which could result into corner point solution and zero inflation problems, data were scaled up by adding a "1." Thus, the score ranged from 1 to 9 where 1 indicates no knowledge and 9 indicates full knowledge of the variable the question referred to.

Before applying factor analysis, the KAP scores were assessed for a high dimensionality problem of multi-collinearity (UCLA 2013). Therefore, the Bartlett sphericity test was used to ascertain if the samples were from populations with equal variances (Williams 2013). The Kaiser-Meyer-Olkin measure of sampling adequacy was also applied to assess whether the sample size was adequate for factor analysis (UCLA 2013). All statistical tests were conducted using Stata 13.1 statistical software (StataCorp LP. STATA 13.1 SE 2015). The level of confidence required for significance was set at $p \leq 0.05$ unless otherwise stated.

Results

Socio-demographic background of respondents

There were 805 respondents who participated in the study, and male and female respondents comprised 58.6 and 41.4 % of the respondents, respectively (Table 1). There were more female and older respondents without a formal education compared to males and their younger counterparts. In addition, the majority of the respondents were subsistent farmers (Table 1). The socio-demographic information of the respondents of this study shows similar trends to the data published by the MNSO (MNSO 2012).

Factor analysis

The Bartlet's sphericity test was highly significant, thereby indicating that the variables were inter-correlated. In addition, the Kaiser-Meyer-Olkin measure of sampling adequacy was 0.79, showing that factor analysis could be used. Factor analysis was then used to reduce dimensionality in the data, and the factors were chosen based on eigenvalues of ≥1 (Kaiser criterion, Kaiser 1958), a scree plot (not shown), and factor loadings of ≥0.40. As a result, only one factor was extracted accounting for 74.9 % of the variance within the data (Table 2). This factor is highly associated with the effect of mold toxins on animal health and the role of humidity on their proliferation. Whereas, their knowledge of the health effects of mold toxins in humans was relatively low, with low loadings regarding their knowledge on the effect of cooking and the association with cancer (Table 2).

Eight important variables capturing respondents' knowledge of: (i) environmental factors that favor mold proliferation, (ii) thermal stability of the mold toxins, and (iii) health effects associated with consumption of contaminated food stuffs were selected from the data.

Knowledge of mold and mycotoxin contamination in foodstuffs

The average KAP score for knowledge of molds among the different categories of respondents was 3.55 ± 1.32 out of a possible 9 (8 variables plus 1), which indicates that knowledge about molds is very low across the sample population (Table 3). There was no statistical differences in the mean scores for age groups between <39 and ≥40 years. However, the study found significant differences in knowledge of mold toxin between female and male respondents ($p < 0.05$) and across education levels of respondents ($p < 0.05$). The data shows that male respondents had more knowledge on toxins than their female counterparts (Table 3). Across the districts, respondents from Mchinji District had significantly higher knowledge scores ($p<0.05$) than respondents from the rest of the districts (Table 3).

Knowledge of molds also varied with the level of education, with those without and with low formal education showing significantly less ($p < 0.1$) knowledge than those that had attained higher levels of formal education. However, only small proportions of respondents were familiar with the terms "mycotoxin" (2.8 %) and "aflatoxin" (11.0 %) (Table 4).

Respondents were also asked to indicate the diseases/disorders that are associated with intake of foodstuffs colonized by molds. Their responses indicate that they have

Table 1 Socio-demographic characteristics of the respondents

Variable		No education	Primary school	Secondary school	Tertiary education	Row totals	Percentage
Sex	Male	52 (15.6)	141 (42.3)	107 (32.1)	33 (9.9)	333 (100)	41.4_s
	Female	96 (20.3)	253 (53.6)	103 (21.8)	20 (4.2)	472 (100)	58.6_s
Age	<39 years	68 (14.5)	214 (45.6)	158 (33.7)	29 (6.2)	469 (100)	58.3_a
	≥40 years	80 (23.8)	180 (53.6)	52 (15.5)	24 (7.1)	336 (100)	41.7_a
Occupation	Farmers	123 (22.1)	334 (60)	95 (17.1)	4 (0.8)	556 (100)	69.1_o
	Medical personnel	0 (0)	0 (0)	9 (50)	9 (50)	18 (100)	2.2_o
	Teachers	0 (0)	0 (0)	10 (47.3)	9 (47.3)	19 (100)	2.4_o
	Agricultural staff	0 (0)	0 (0)	2 (22.2)	7 (77.7)	9 (100)	1.1_o
	Others	27 (12.5)	77 (35.8)	101 (47)	12 (5.6)	215 (100)	26.7_o

$N = 805$; Numbers in brackets denote percentages; values with the same subscript under the "Percentage" add up to 100

Table 2 Varimax rotated factor structure of the eight items of knowledge on mold toxin

Variable	Factor loading
Health effects	
Toxins can cause stunting	–
Toxins can cause liver cancer	0.4098
Toxins can harm livestock	0.9132
Toxins suppress human immunity	–
Stability of the mold toxins	
Toxins survive normal cooking	0.5941
Toxins can accumulate in animal products	0.8139
Environmental factors	
Toxins can build up in humid conditions	0.8136
Toxins can build up in high temperatures	–

Blanks represent |loading| < 0.3

Table 3 Differences in knowledge among demographic groups

Variables	Mean	Std. dev.	Freq.	Test-stat	Sig.
Age					
39 and below	3.5532a	1.2977	235	1.09	
40 and above	3.5456a	1.3305	570		
Total	3.5478	1.3202	805		
Sex					
Male	3.7808a	1.2976	333	18.06	**
Female	3.3835b	1.3127	472		
Total	3.5478	1.3202	805		
Education level					
None	3.6216b	1.4257	148	2.71	*
Primary-Standard 1–4	3.3871b	1.3538	124		
Primary-Standard 5–8	3.4074b	1.3207	270		
Secondary-Form 1–2	3.6250ab	1.2347	88		
Secondary-Form 3–4	3.7377a	1.2318	122		
Tertiary education	3.8679ab	1.1773	53		
Total	3.5478	1.3202	805		
District					
Blantyre	3.3131b	1.1307	99	9.73	**
Chikwawa	3.4044b	1.3131	136		
Mangochi	3.3600b	1.2208	125		
Mchinji	4.3652a	1.3267	115		
Mzimba	3.5645b	1.2574	124		
Ntcheu	3.3100b	1.3684	100		
Thyolo	3.4906b	1.3183	106		
Blantyre	3.3131b	1.1307	99		
KAP score (1–9)	3.5478	1.3202	805		

Number in brackets is the range. Same letters in a column indicate that means are not significantly different from each other using Tukey's pairwise comparisons.

$^{**}p<0.05$; $^{*}p<0.1$

limited knowledge of the specific health complications that may arise from consuming moldy foodstuffs. About 12 % of the respondents did not consider moldy food to be dangerous. Further, the majority (74 %) of respondents considered bacterial hazards to be more dangerous or equal to fungal toxins (Table 4).

Although the majority (88 %) of the respondents considered consumption of moldy food to be dangerous, a significant proportion (50 %) thought fungal toxins are destroyed by normal cooking. Similarly, 10 % of the respondents had a perception that feedstuffs with severe mold colonization were not harmful to livestock, whereas a similar percentage (9.0 %) had a contrary opinion to the fact that toxins consumed by livestock could potentially be carried on into other animal products such as egg, meat, and milk. These results can also been seen in factor analysis characterized by high loadings for the effect of mold toxins on animal health and carryover into animal products (Table 2).

Molds can grow on any kind of food matrices, although some foods provide better substrate for growth than others (Afsah-Hejri et al. 2013). However, when asked to list food commodities that they knew as being susceptible to mold contamination, respondents highlighted maize (50.9 % of respondents), groundnuts (37.5 %), tubers (29.4 %), and pulse (14.8 %). Bambara nuts, sorghum, millet, fruits, and vegetables were listed by less than 5 % of the respondents. In general, the majority of the respondents reported that they consume moldy food stuffs due to food shortage (Table 4). About 20 % of respondents reported that they consume moldy fruits because they remove and discard the moldy part and only consume the part without contamination.

Responses to knowledge questions related to favorable environmental conditions for mold development and management of cultural practices are presented in Table 5. Approximately 91 % of the respondents had a fairly high knowledge of the role of moisture in mold development but they generally had low knowledge (8–29 %) of the role of pre- and post-harvest management practices (Table 5). In addition, very few respondents (~25 %) highlighted that placing food commodities directly on the floor or bare ground may also increase the risk of mold growth.

Considering that maize is a main food staple for Malawi, some questions were specifically tailored to capture behavior and knowledge regarding molds in maize and the findings are summarized in Table 6. About 30 % of the population asserted to buying moderately moldy maize grains, citing shortage of the grain on the market as the major reason. As regards processes that are employed to reduce mold contamination of grains, almost all respondents indicated that they winnow maize and a significant proportion of the population reported to hand sort their maize before dehulling or milling (Table 6). However, the sorting was said to be carried out unsystematically (picking the grains and not pushing the bad grains to one

Table 4 Responses regarding types of foodstuffs that are consumed despite being moldy and reasons

Item	Percentage
Foodstuffs that are consumed despite prevalence of molds	
Groundnuts	41.3
Fresh fruits	36.3
Dried fruits	1
Cassava	31.0
Dried meat products	2.4
Dried fish	7.4
Dried vegetable	4.7
Reasons for consuming moldy foodstuffs	
Shortage of food	52.5
Small fraction of moldy has no effect on taste or/and flavor	1.4
Small moldy part will not sicken me	4.1
I eat moldy foodstuff, I am always healthy	0.8
My ancestors lived on the same diet	0.5
For fruits, I remove the moldy fraction and eat the health part	21.5
I wash to remove molds	6.5
Moldy foodstuff cannot kill me	1.4
Cheaper on the market	2.4
Familiar with the terms	
Aflatoxins	11.0
Mycotoxins	2.8
Respondents listing of diseases/disorders that may arise from consuming moldy foodstuffs	
Purging	46.7
Stomachache	43.7
Numerous diseases	15.0
Cancer	8.6
Immunosuppression	4.8
Vomiting	4.7
Coughing	4.4
Stunting	4.4
Headache	3.0
Fever	2.4

side and sound grains to the other side as described by Matumba et al. 2015c). Labor intensity (8 %) and reduction of volume (12 %) were among important barriers to hand sorting of maize grains (Table 6).

Discussion

The survey was conducted to assess the respondents' knowledge, attitudes, and practices on mold colonization of their foodstuffs, as a precursor of mycotoxins, and the associated health risks. The data from this study indicates that most of the respondents showed low knowledge of the link of mold colonization and the health risk factors associated with mycotoxins such as aflatoxins. This observation is supported as a large number of people in both developing and developed countries are not aware of risk associated with contaminated food (Siegrist and Cvetkovich 2000). In this study, female participants were found to be significantly less knowledgeable (Table 3) than their male counterparts. However, in African culture, women have a predominant role in food production and utilization (Gittinger 1990). The relatively lower knowledge among the females could be partially attributed to the fact that a larger proportion of this group also indicated attainment of no or low levels of formal education (Table 1). Indeed, the level of formal education attained seemed to have a statistically significant effect ($p < 0.1$) on respondent's knowledge about the molds in food (Table 3). However, it seems this effect is more from transferrable skills as mycotoxin issues are not explicitly covered in the Malawian curricula at primary and secondary school levels. No wonder only small

Table 5 Responses to knowledge questions related to favorable environmental conditions for mold development and management cultural practices

Item	Percentage
Major environment factors reported to favor the development of mold in food	
Temperature	14.4
Humidity/moisture/prolonged rainfall season	90.6
Abundance of fungi or fungal spores	5.2
Insect damage	12.3
Major practices reported to favor mold development in food	
Storing food inadequately dried foods	71.9
Placing food commodities on bare grounds	24.8
Keeping food in humid/leaky stores	60.3
Over storage of food commodities	1.4
Knowledge of pre-harvest control strategies	
Early planting	8.4
Crop rotation	4.9
Proper soil nutrient management	5.5
Genotype of seed of seed	10.1
Irrigation	1.2
Insecticides	42.3
Timing of harvest	52.6
Knowledge of post-harvest control strategies	
Hand sorting	27.8
Adequate rapid drying	72.7
Avoiding of floor/wall contact	43.3
Rodent control	12.9
Winnowing	11.6
Dehulling	4.1
Washing	8.5

Table 6 Behavior and knowledge related to presence of molds in maize

Item	Percentage
Buy moldy grain	
Moderately moldy	27.8
Heavily moldy	4.9
Reasons for buying moldy maize	
Scarcity of grains	27.0
Lower prices	9.6
Doesn't matter, dehulling removes toxins	2.5
Doesn't matter, it is harmless	1.8
Processing	
Winnowing	98.5
Sort maize before dehulling/milling	87.1
Benefits of hand sorting	
Sorting is hygienic	79.8
Sorting reduce pests	14.0
Clean grains give a better produce price	4.4
Clean grains sell faster	4.4
Reasons for not sorting maize	
Sorting can reduce volume	12.1
Not important	10.0
Laborious	7.9
Time consuming	4.2
Too costly	3.2
Eating few discolored maize will not sicken me	1.5

proportions of respondents were familiar with the terms "mycotoxin" (2.8 %) and "aflatoxin" (11.0 %) (Table 4). People with higher education level are likely to be better informed, and therefore, may be more aware of some types of risk of food additives or pesticides in foods than those with less education (Dosman et al. 2001). In fact, respondents from Mchinji district, where there is an active awareness campaign of aflatoxin issues (Matumba et al. 2015b) ran by a National Association of Smallholder Farmers (NASFAM) among its cooperative members, obtained significantly higher KAP scores than respondents from the rest of the districts (Table 3).

Mycotoxins (such as aflatoxins) are associated with several severe human (e.g., Jolly et al. 2007) and animal health conditions (Pier et al. 1980; Fink-Grernmels 1999; Osweiler 2000). In its acute stages, aflatoxicosis is associated with high fever, rapid progressive jaundice, edema of the limbs, pain, vomiting, and swollen livers (Food and Drug Administration 2012). Whereas chronic aflatoxicosis has no clear symptoms and results from sustained exposure at sub-lethal doses, and is characterized by suppression of immunity and nutritional status (Williams et al. 2004; Jiang et al. 2005). In this study, the respondents showed a general lack of awareness of the health effects associated with molds and mycotoxins to humans. This is reflected in the results of the factor analysis, with low factor loadings on variables related to human health (Table 2). Some respondents associated consumption of moldy foodstuffs with diseases such as malaria, which in Malawi is blamed for the majority of high fever symptoms. The majority of the responders linked mycotoxins with acute health effects (purging and stomachache) and not chronic effects (Table 4). They ranked bacterial hazards to be more dangerous than or the same as fungal toxins. Indeed, as far as acute toxicity is concerned, microbial contaminants are generally more important compared to mycotoxins (Kuiper-Goodman 1998). However, mycotoxins rank top on the list of chronic food toxicants. Unlike microbial contaminants, mycotoxins often occur in doses far below those responsible for acute effects, but may induce long-term syndromes (such as cancer) (Smith et al. 1995), cause stunting, and depress immunity (Berek et al. 2001; Corrier 1991; Sharma 1993). Since these effects are long term, it may be difficult to link the health effects to the causative agents. It is noteworthy that Malawi has the highest esophageal cancer prevalence rate (24.2 per 100,000 people) in the world (Ferlay et al. 2013) which could be attributed to high dependence on maize and high fumonisin levels (Matumba et al. 2014). Fumonisin dietary exposure is linked to esophageal cancer (Rheeder et al. 1992; Sun et al. 2007). Unfortunately, the current national efforts are solely focused on aflatoxins, a situation that is similar in most African countries (Matumba et al. 2015a).

Most mycotoxins are known to be generally thermally stable and are therefore not destroyed during most normal cooking processes (Bullerman and Bianchini 2007; Raters and Matissek 2008). Moreover, some thermal processes have been reported to yield products that are as toxic as their parent mycotoxins (Dombrink-Kurtzman et al. 2000; Voss et al. 2001) or to be reversible under simulated gastrointestinal tract conditions, e.g., the case of aflatoxin and nixtamalization of maize (Méndez-Albores et al. 2004). Regarding effect of moldy feedstuff on livestock, studies have shown that toxins consumed by livestock negatively affect productivity and may potentially be carried on into other animal products such as egg, meat, and milk (Bryden 2012; Gareis and Wolff 1999; Volkel et al. 2011). Therefore, ignorance of these facts displayed by some respondents in the current study indicates that mycotoxin dietary exposure from associated foodstuffs is likely.

Most of the respondents recognized the major crops that are susceptible to molds, such as maize and groundnuts. It is worth noting that the high counts for these formal food commodities may not necessarily reflect the order of known susceptibility to molds but rather the importance attached to the crops in Malawi. Some of the respondents also asserted to consume mold-colonized foodstuffs such as maize grains and fruits. In the case of fruits, they reported that they consume moldy fruits because they remove and discard the moldy part and only consume the non-contaminated part. However, mycotoxins are known to diffuse from the parts colonized by molds to the unaffected areas (Beretta et al. 2000; Engelhardt et al. 1999; Martins et al. 2002; Taniwaki et al. 1992). The mycotoxins mostly associated with fruits are patulin, aflatoxins, *Alternaria* toxins, and ochratoxin A (Jackson and AL-Taher 2008). Since the tropical conditions prevailing in Malawi favor the proliferation of fungi in fruits, the risk of mycotoxin dietary exposure from fruits is likely to be high (Barkai-Golan and Paster 2008). It is therefore imperative that Malawians be informed about feasible and “easy to handle” strategies for control of fungal infection of fruits (Tripathi and Dubey 2004).

The development of molds and mycotoxin production is highly dependent on environmental factors (e.g., temperature, moisture content, insect damage, and presence of fungal spores) and pre- and post-harvest cultural practices (Lacey 1989; Milani 2013; Northolt and Bullerman 1982; Pitt et al. 2000; Sanchis and Magan 2004; St. Leger et al. 2000). Knowledge of these factors is key to management of molds and mycotoxins, particularly for farmers/producers. In this study, it was clear that the respondents could link humidity and some pre- and post-harvest practices to mold colonization (Table 5). This is also reflected in factor analysis as there is a high factor loading for the role of humidity on mold proliferation. However, approximately 85 % of the population in Malawi are subsistent producers/consumers (Harrigan 2008) and a large proportion of houses in Malawi are poorly maintained with leaking roofs and poor ventilation (MNSO 2012) which inevitably increase the chance of mold proliferation in stored foodstuffs. Worse still, very few respondents (~25 %) highlighted that placing food commodities directly on the floor or bare ground may also increase the risk of molds growth. Similar findings were reported by Hell and co-authors (Hell et al. 2000).

This study also brought out barriers, defined as the social, financial, and economic obstacles that may prevent someone from taking actions to control molds and mycotoxins in foodstuffs. The major barriers can be categorized into economic and knowledge factors. The majority highlighted shortage of food as a reason for consuming moldy foodstuffs (Table 4), scarcity of maize as a reason for buying moldy maize, and reduction in volume for not sorting maize (Table 6). Indeed, Malawi faces recurrent grain shortage (Harrigan 2008). Whereas, others thought that it was not important to sort maize (Table 6) and that removing the moldy fraction of fruit makes it safer consumption (Table 4).

Conclusion and perspectives

The study has provided valuable insights into public’s knowledge, attitude, and practice regarding molds in food in Malawi. The findings have clearly demonstrated that the public is not well informed of the health implications associated with moldy food- and feedstuffs. This renders both the public and livestock vulnerable. It is therefore recommended that policies be designed to build awareness programs about the health risks associated with spoilage molds in food (and not only focusing on aflatoxins) and the social and economic benefits of reducing this risk. Transmitting information (i.e., knowledge) on how habits affect health is recognized as an effective mechanism in which knowledge could induce a change in mindset (Bandura 2004; Meyerowitz and Chaiken 1987).

Integrating the topic into agricultural and health sciences subjects from as early as from primary school could be much more effective. Unless the general public is equipped with adequate information on the health problems associated with mycotoxins and their prevention and management options, they will continue to carry the moldy foodstuffs from fields onto their tables.

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Compliance with ethical standards

Conflict of interest The authors declare no competing financial interests.

References

Afsah-Hejri L, Jinap S, Hajeb P, Radu S, Shakibazadeh S (2013) A review on mycotoxins in food and feed: Malaysia case study. Compr Rev Food Sci Food Saf 12:629–651

Bandura A (2004) Health promotion by social cognitive means. Health Educ Behav 31:143–164

Barkai-Golan R, Paster N (2008) Mouldy fruits and vegetables as a source of mycotoxins: part 1. World Mycotoxin J 1:147–159

Bennett JW, Klich M (2003) Mycotoxins. Clin Microbiol Rev 16:497–516

Berek L, Petri IB, Mesterhazy A, Téren J, Molnár J (2001) Effects of mycotoxins on human immune functions in vitro. Toxicol In Vitro 15:25–30

Beretta B, Gaiaschi A, Galli CL, Restani P (2000) Patulin in apple-based foods: occurrence and safety evaluation. Food Addit Contam 17: 399–406

Bruns HA (2003) Controlling aflatoxin and fumonisin in maize by crop management. Toxin Rev 22:153–173

Bryden WL (2012) Mycotoxin contamination of the feed supply chain: implications for animal productivity and feed security. Anim Feed Sci Technol 173:134–158

Bullerman LB, Bianchini A (2007) Stability of mycotoxins during food processing. Int J Food Microbiol 119:140–146

Chulze SN (2010) Strategies to reduce mycotoxin levels in maize during storage: a review. Food Addit Contam Part A 27:651–657

Corrier DE (1991) Mycotoxicosis: mechanisms of immunosuppression. Vet Immunol Immunopathol 30:73–87

Dombrink-Kurtzman MA, Dvorak TJ, Barron ME, Rooney LW (2000) Effect of nixtamalization (alkaline cooking) on fumonisin-contaminated corn for production of masa and tortillas. J Agric Food Chem 48:5781–5786

Dosman DM, Adamowiez WL, Hrudey SE (2001) Socioeconomic determinants of health- and food safety-related risk perceptions. Risk Anal 21:307–317

Engelhardt G, Ruhland M, Wallnöfer PR (1999) Occurrence of ochratoxin A in moldy vegetables and fruits analysed after removal of rotten tissue parts. Adv Food Sci 21:88–92

Ezekiel CN, Sulyok M, Babalola DA, Warth B, Ezekiel VC, Krska R (2013) Incidence and consumer awareness of toxigenic Aspergillus section Flavi and aflatoxin B1 in peanut cake from Nigeria. Food Control 30:596–560

Ferlay J, Soerjomataram I, Ervik M, Dikshit R, Eser S, Mathers C, Rebelo M, Parkin, D.M., Forman, D. and Bray, F., 2013.GLOBOCAN 2012 v1.0 cancer incidence and mortality worldwide: IARC Cancer Base No. 11. International Agency for Research on Cancer, Lyon, France. http://globocan.iarc.fr. Accessed 20 October 2015

Fink-Grernmels J (1999) Mycotoxins: their implications for human and animal health. Vet Q 21:115–120

Food and Drug Administration (2012) Bad Bug Book: Foodborne Pathogenic Microorganisms and Natural Toxins Handbook Aflatoxins. http://www.fda.gov/Food/FoodborneIllnessContaminants/CausesOfIllnessBadBugBook/ucm071020.htm. Accessed 20 August 2015

Fung F, Clark RF (2004) Health effects of mycotoxins: a toxicological overview. J Toxicol Clin Toxicol 42:217–234

Gareis M, Wolff J (1999) Relevance of mycotoxin contaminated feed for farm animals and carryover of mycotoxins to food of animal origin. Mycoses 43:79–83

Gittinger JR (1990) Household food security and the role of women. World Bank Discussion Paper No. 96. World Bank: Washington DC, United States of America

Harrigan J (2008) Food insecurity, poverty and the Malawian starter pack: fresh start or false start? Food Policy 33:237–249

Hell K, Cardwell KF, Setamou M, Poehling HM (2000) The influence of storage practices on aflatoxin contamination in maize in four agro-ecological zones of Benin, West Africa. J Stored Prod Res 36:365–382

Hussein HS, Brasel JM (2001) Toxicity, metabolism, and impact of mycotoxins on humans and animals. Toxicology 167:101–134

Ilesanmi FF, Ilesanmi OS (2011) Knowledge of aflatoxin contamination in groundnut and the risk of its ingestion among health workers in Ibadan, Nigeria. Asian Pac J Trop Biomed 1:493–495

Jackson LS, AL-Taher F (2008) Factors affecting mycotoxin production in fruits. In: Barkai-Golan R, Paster N (eds) Mycotoxins in fruits and vegetables. Elsevier, San Diego, pp 75–104

James B, Adda C, Cardwell K, Annang D, Hell K, Korie S et al (2007) Public information campaign on aflatoxin contamination of maize grains in market stores in Benin, Ghana, and Togo. Food Addit Contam 24:1283–1291

Jiang Y, Jolly PE, Ellis WO, Wang JS, Phillips TD, Williams JH (2005) Aflatoxin B1, albumin adduct levels and cellular immune status, in Ghanaians. Int J Microbiol Immunol Res 17:807–814

Jolly PE (2014) Aflatoxin: does it contribute to an increase in HIV viral load? Future Microbiol 9:121–124

Jolly PE, Jiang YE, William O, Awuah RT, Appawu J, Nnedu O, Stiles JK, Wang J-S, Adjei O, Jolly CM, William JH (2007) Association between aflatoxin exposure and health characteristics, liver function, hepatitis and malaria infections in Ghanaian. J Nutr Environ Med 16:1–16

Jolly CM, Bayard B, Awuah RT, Fialor SC, Williams JT (2009) Examining the structure of awareness and perceptions of groundnut aflatoxin among Ghanaian health and agricultural professionals and its influence on their actions. J Socio-Econ 38:280–287

Jolly PE, Inusah S, Lu B, Ellis WO, Nyarko A, Phillips TD, Williams JH (2013) Association between high aflatoxin B1 levels and high viral load in HIV-positive people. World Mycotoxin J 6:255–261

Kaaya AN, Harris C, Eigel W (2006) Peanut aflatoxin levels on farms and in markets of Uganda. Pean Sci 33:68–75

Kaiser HF (1958) The varimax criteria for analytical rotation in factor analysis. Psychometrika 23:187–200

Kessler CA (2006) Decisive key-factors influencing farm households' soil and water conservation investments. Appl Geogr 26:40–60

Kuiper-Goodman T (1998) Food safety: mycotoxins and phytotoxins in perspective. In: Miraglia M, van Egmond H, Brera C, Gilbert J (eds) Mycotoxins and phycotoxins—developments in chemistry, toxicology and food safety. Alken Inc, Fort Collins, pp 25–48

Lacey J (1989) Pre-and post-harvest ecology of fungi causing spoilage of foods and other stored products. J Appl Bacteriol 67:11s–25s

Lewis L, Onsongo M, Njapau H, Rogers HS, Luber G, Kieszak S et al (2005) Aflatoxin contamination of commercial maize products during an outbreak of acute aflatoxicosis in eastern and central Kenya. Environ Health Perspect 113:1763–1767

Liu CW, Lin KH, Kuo YM (2003) Application of factor analysis in the assessment of groundwater quality in a blackfoot disease area in Taiwan. Sci Total Environ 313:77–89

Malachova A, Sulyok M, Beltrán E, Berthiller F, Krska R (2014) Optimization and validation of a quantitative liquid chromatography–tandem mass spectrometric method covering 295 bacterial and fungal metabolites including all regulated mycotoxins in four model food matrices. J Chromatogr A 1362: 145–156

Martins ML, Gimeno A, Martins HM, Bernardo F (2002) Co-occurrence of patulin and citrinin in Portuguese apples with rotten spots. Food Addit Contam 19:568–574

Matumba L, Sulyok M, Monjerezi M, Biswick T, Krska R (2014) Fungal metabolites diversity in maize and associated human dietary exposures relate to micro-climatic patterns in Malawi. World Mycotoxin J 8:269–282

Matumba L, Van Poucke C, Ediage EN, De Saeger S (2015a) Keeping mycotoxins away from the food: does the existence of regulations have any impact in Africa? Crit Rev Food Sci Nutr. doi:10.1080/10408398.2014.993021

Matumba L, Van Poucke C, Monjerezi M, Ediage EN, De Saeger S (2015b) Concentrating aflatoxins on the domestic market through groundnut export: a focus on Malawian groundnut value and supply chain. Food Control 51:236–239

Matumba L, Van Poucke C, Njumbe Ediage E, Jacobs B, De Saeger S (2015c) Effectiveness of hand sorting, flotation/washing, dehulling and combinations thereof on the decontamination of mycotoxin-contaminated white maize. Food Addit Contam Part A 32:960–969

Mboya RM, Kolanisi U (2014) Subsistence farmers' mycotoxin contamination awareness in the SADC region: implications on Millennium Development Goal 1, 4 and 6. J Hum Ecol 46:21–31

Méndez-Albores JA, Villa GA, Rio-García D, Martinez EM (2004) Aflatoxin-detoxification achieved with Mexican traditional nixtamalization process (MTNP) is reversible. J Sci Food Agric 84:1611–1614

Meyerowitz BE, Chaiken S (1987) The effect of message framing on breast self-examination attitudes, intentions, and behaviors. J Pers Soc Psychol 50:500–510

Milani JM (2013) Ecological conditions affecting mycotoxin production in cereals: a review. Vet Med - Czech 58:405–411

MNSO (2012) Malawi Third Integrated Household Survey (IHS3) 2010–11 basic information document. Malawi National Statistical Office, Zomba

Northolt MD, Bullerman LB (1982) Prevention of mold growth and toxin production through control of environmental conditions. J Food Prot 45:519–526

Oswald IP, Marin DE, Bouhet S, Pinton P, Taranu I, Accensi F (2005) Immunotoxicological risk of mycotoxins for domestic animals. Food Addit Contam 22:354–360

Osweiler GD (2000) Mycotoxins. Contemporary issues of food animal health and productivity. Vet Clin North Am Food Anim Pract 16: 511–530

Pedrosa K, Borutova R (2011) Synergistic effects of mycotoxins discussed. Feedstuffs 83:1–3

Peraica M, Radic B, Lucic A, Pavlovic M (1999) Toxic effects of mycotoxins in humans. Bull World Health Organ 77:754–766

Pestka JJ, Tai JH, Witt MF, Dixon DE, Forsell JH (1987) Suppression of immune response in the B6C3F 1 mouse after dietary exposure to the Fusarium mycotoxins deoxynivalenol (vomitoxin) and zearalenone. Food Chem Toxicol 25:297–304

Pier AC, Richard JL, Cysewski SJ (1980) Implications of mycotoxins in animal disease. J Am Vet Med Assoc 176:719–724

Pitt JI, Basilico JC, Abarca ML, Lopez C (2000) Mycotoxins and toxigenic fungi. Med Mycol 38:41–46

Raters M, Matissek R (2008) Thermal stability of aflatoxin B1 and ochratoxin A. Mycotoxin Res 24:130–134

Reddy KRN, Salleh B, Saad B, Abbas HK, Abel CA, Shier WT (2010) An overview of mycotoxin contamination in foods and its implications for human health. Toxin Rev 29:3–26

Rheeder JP, Marasas WFO, Thiel PG, Sydenham EW, Shephard GS, Van Schalkwyk DJ (1992) Fusarium moniliforme and fumonisins in corn in relation to human oesophageal cancer in Transkei. Phytopathology 82:353–357

Sanchis V, Magan N (2004) Environmental profiles for growth and mycotoxin production. In: Magan N, Olsen M (eds) Mycotoxins in food: detection and control. Woodhead Publishing Ltd, Cambridge, pp 174–189

Sandra V, McNeel DVM, Richard A, Kreutzer MD (1996) Fungi and indoor air quality. Health Environ Digest 10:6–12

Sharma RP (1993) Immunotoxicity of mycotoxins. J Dairy Sci 76:892–897

Siegrist M, Cvetkovich G (2000) Perception of hazards: the role of social trust and knowledge. Risk Anal 20:713–719

Smith LI (2002) A tutorial on principal component analysis. Ithaca, New York: Cornell University. www.cs.otago.ac.nz/cosc453/student_tutorial s/principal_components. pdf. Accessed 22 October 2015

Smith JE, Solomons G, Lewis C, Anderson JG (1995) Role of mycotoxins in human and animal nutrition and health. Nat Toxins 3:187–192

Speijers GJA, Speijers MHM (2004) Combined toxic effects of mycotoxins. Toxicol Lett 153:91–98

St. Leger RJ, Screen SE, Shams-Pirzadeh B (2000) Lack of host specialization in Aspergillus flavus. Appl Environ Microbiol 66::320–324

StataCorp LP. STATA 13.1 SE. 2015. http://www.stata.com/ Accessed 10 September 2015

Strosnider H, Azziz-Baumgartner E, Banziger M, Bhat RV, Breiman R, Brune MN et al (2006) Workgroup report: public health strategies for reducing aflatoxin exposure in developing countries. Environ Health Perspect 114:1898–1903

Sulyok M, Berthiller F, Krska R, Schuhmacher R (2006) Development and validation of a liquid chromatography/tandem mass spectrometric method for the determination of 39 mycotoxins in wheat and maize. Rapid Commun Mass Spectrom 20:2649–2659

Sulyok M, Krska R, Schuhmacher R (2007) A liquid chromatography/tandem mass spectrometric multi-mycotoxin method for the quantification of 87 analytes and its application to semi-quantitative screening of moldy food samples. Anal Bioanal Chem 389:1505–1523

Sulyok M, Krska R, Schuhmacher R (2010) Application of an LC–MS/MS based multi-mycotoxin method for the semi-quantitative determination of mycotoxins occurring in different types of food infected by moulds. Food Chem 119:408–416

Sun G, Wang S, Hu X, Su J, Huang T, Yu J, Tang L, Gao W, Wang JS (2007) Fumonisin B1 contamination of home-grown corn in high-risk areas of esophageal and liver cancers in China. Food Addit Contam 24:181–185

Taniwaki MH, Hoenderboom CJM, Vitali ADA, Eiroa MNU (1992) Migration of patulin in apples. J Food Prot 55:902–904

Tripathi P, Dubey NK (2004) Exploitation of natural products as an alternative strategy to control postharvest fungal rotting of fruit and vegetables. Postharvest Biol Technol 32:235–245

UCLA: Statistical Consulting Group (2013) Stata annotated output: factor analysis. http://www.ats.ucla.edu/stat/stata/output/fa_output.htm. Accessed 20 August 2015

Volkel I, Schroer-Merker E, Czerny CP (2011) The carry-over of mycotoxins in products of animal origin with special regards to its implications for the European food safety legislation. Food Nutr Sci 2: 852–867

Voss KA, Poling SM, Meredith FI, Bacon CW, Saunders DS (2001) Fate of fumonisins during the production of fried tortilla chips. J Agric Food Chem 49:3120–3126

Williams R (2013) Using stata for one-way analysis of variance. http://www3.nd.edu/~rwilliam/stats1/Oneway-Stata.pdf. Accessed 24 October 2015

Williams JH, Phillips TD, Jolly PE, Stiles JK, Jolly CM, Aggarwal D (2004) Human aflatoxicosis in developing countries: a review of toxicology, exposure, potential health consequences and interventions. Am J Clin Nutr 80:1106–1122