



Occurrence and factors associated with aflatoxin contamination of raw peanuts from Lusaka district's markets, Zambia



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ABSTRACT

Peanuts, one of the most susceptible crops to aflatoxin (AF) contamination, are widely produced and consumed in Zambia. This cross-sectional study was designed to determine the levels of AFs in raw peanuts sold in Lusaka district's markets as well as identify factors associated with increased AF presence. Raw peanut samples were collected from open markets and supermarkets and analyzed for aflatoxin contamination using high performance liquid chromatography (HPLC). A questionnaire was also administered to the peanut vendors to investigate factors contributing to increased levels of AFs in peanuts. Of the 92 samples, 51 (55.4%; 95% CI: 44.9–65.4) tested positive for presence of AFs. The overall median and geometric mean $\pm$ standard deviation (SD) concentration for AF were 0.23 ppb (range: 0.014–48.67 ppb) and 0.43 ± 9.77 ppb, respectively. The association between market types and presence of AFs was not statistically significant (Pearson $\chi^2 = 0.0587$, $p = 0.809$). Of 51 samples that tested positive to AF, 6.5% and 12% were above the maximum permissible limits (MPLs) set by the Codex Alimentarius Commission and European Union standards, respectively. There was a significant difference in the levels of AF between *Chalimbana* and *Kadononga* ($p < 0.0001$), and also *Chalimbana* and *Makulu red* ($p < 0.0001$). *Chalimbana* was the most at risk of AF contamination, when compared to other peanut varieties. The high level of AFs in raw peanuts from both supermarkets and open markets samples constitutes a health hazard for the population of Lusaka district. Therefore, intervention strategies that reduce the levels of AF contamination in peanuts should be given priority.

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1. Introduction

Aflatoxins (AFs) are toxic metabolites of fungi (*Aspergillus* sp) that constitute one of the major food safety challenges (Unnevehr & Grace, 2013). Aflatoxins contaminate a large fraction of the world's food and feed commodities (Strosnider et al., 2006). Maize, peanut and cottonseed are the major crops affected by AFs (Cotty, Probst, & Jaime-Garcia, 2008; Kpodo, Thrane, & Hald, 2000). Human exposure to AF may primarily occur through contaminated intake (IARC,

2002), and secondarily from exposure to air and dust containing toxins released during the handling of contaminated products (Sorenson, Jones, Simpson, & Davidson, 1984).

Several harmful effects of AFs in both humans and animals have been described. These include liver cirrhosis, liver cancer, immune-system suppression, growth retardation for children and even death (Azziz-Baumgartner et al., 2005; Gong et al., 2004; Wild & Turner, 2002; Williams et al., 2004). Due to its hepatocarcinogenic effect, the International Agency for Research on Cancer (IARC) has classified aflatoxin B1 (AFB1) as a group 1 carcinogenic agent to humans (IARC, 2002).

In addition to their effects on human and also animal health, AFs constitute an economic burden. In fact, aflatoxin contamination of various agricultural products causes enormous losses to both

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farmers (loss of livelihood) and the country through export bans which introduces additional cost in the treatment or rejection of banned products (Wu, Narrod, Tiongo, & Liu, 2011). Furthermore, the most susceptible crops to AF contamination (maize and groundnuts) are staple foods in most African communities (Wu and Khlangwiset, 2010). Therefore, any hazard occurring in these products is likely to affect a large population hence increasing poverty and food insecurity.

Since it is difficult to achieve zero tolerance with AF contamination in commodities, the Joint FAO/WHO Expert Committee on Food Additives (JECFA) recommends that dietary exposure to AFs should be minimized as much as possible to prevent the risk of cancer (JECFA, 2008). Thus, legal tolerance limits based on scientific evidence obtained from risk assessment in different countries have been set for AFB1 and total aflatoxin (AF) in foods that are destined for human consumption (Wu, Stacy, & Kensler, 2013). The limits vary between 4 and 20 parts per billion (ppb) (Wu et al., 2013). The Codex Alimentarius Commission (CAC), Joint FAO/WHO Food Standards Program adopted levels of 15 ppb as maximum permissible limits (MPLs) for AF in unprocessed peanuts and tree nuts, and 10 ppb in ready-to-eat tree nuts (CAC, 2014). The European Union (EU) has the most stringent standards of AFs in the world with a limit of 4 ppb for AF (Wu et al., 2013). In most African countries aflatoxin is largely unregulated. In 2013, aflatoxin regulations were present in ten African countries (Wu et al., 2013). Zambia is one of the African countries that does not have its own regulation on AF but rely solely on the Codex Alimentarius Standards despite the fact that most of the staple diets in the country (maize, peanuts, and their products) (JAICAF, 2008; Sitko et al., 2011) are susceptible to AF contamination.

In Zambia, peanut production is high and contributes significantly to the national economy (Sitko et al., 2011). However, little is known about the magnitude of AF contamination in Zambian peanuts. Furthermore, there is currently no study in Zambia estimating the levels of AFs in peanuts sold at different markets. This study was carried out to measure the levels of AFs in raw peanuts sold in Lusaka district's markets as well as identify factors associated with increased AF presence in the Zambian peanut crops.

2. Materials and method

2.1. Survey and sample collection

A cross-sectional study design was conducted in Lusaka district's markets for a period of one (1) month, March 2015. Lusaka district was purposively selected because its markets receive agricultural products from all provinces of the country, other African countries and the world.

Market selling points for peanuts were categorised into open markets and supermarkets. An open market was defined as a market not housed in a building, where foodstuffs are sold exposed in the open air and spread on shelves or the ground; while a supermarket was defined as a market housed in a closed building with modernised facilities, i.e. shopping mall.

A list of open markets ($n = 57$) and supermarkets ($n = 12$) in Lusaka district formed the sampling frame of the study. Assuming that AFs in peanuts in Zambia occurred at 80% prevalence; and that we wanted to be 95% confident in estimating the true prevalence while allowing only 5% estimation error, the sample size was estimated using the formula for simple random sampling (Lwanga & Lemeshow, 1991).

Based on the above assumptions and after adjusting for fine population, a total number of 32 markets formed part of the study. Using a proportional stratified random sampling, a total of 26 open markets and 6 supermarkets were included in the study. Within

each stratum (type of market), simple random sampling was done to obtain the required number of markets ensuring that all the seven constituencies of Lusaka district were represented. From each open market, at least 3 vendors were randomly sampled or 10% of them if the number was large. From each selected vendor, 500 g of raw peanuts samples were purchased. Similarly, from each supermarket, at least 500 g of raw peanuts of each variety were purchased. Further, a questionnaire was administered to those vendors to collect information on factors suspected to explain the occurrence of AFs in these products. Thus, 92 raw peanut samples were purchased with 73 from the open markets and 19 from the supermarkets.

2.2. Aflatoxins determination

Samples were analyzed in the chemistry laboratory at Zambian Agriculture Research Institute (ZARI) using AflaTest[®] test kit with HPLC method certified by the AOAC[®] Official Methods Program, as official method 991.31 applicable for the determination of aflatoxin B1, B2, G1 and G2 both by fluorometry and HPLC analysis in corn, peanuts and peanut butter.

Acetonitrile and methanol were purchased from Sigma–Aldrich[®] (Germany). For high-performance liquid chromatography, HPLC-grade reagents were used. Aflatoxin B1, B2, G1 and G2 standards were purchased from Trilogy Analytical Laboratory (USA) (Lot 120316–090, Total concentration AF: 5.0 µg/ml, Total aflatoxin B1, B2, G1, G2: 4/1/4/1). The concentration was determined according to AOAC International Official Methods of Analysis. An immunoaffinity column (IAC), the AflaTest[®] column (Vicam, Watertown, MA, USA), was used for cleaning the samples.

In order to minimize the sub-sampling error in AFs analysis, all the samples were ground using a domestic grinder (Jura-CAPRESSO INC, Model N°503, China) and 25 g of each ground sample with 5 g NaCl were weighed and mixed for analysis.

The mixture was placed in a blender jar for extraction using 125 ml of methanol: water (70:30). The solution was blended at high speed for 2 min and then filtered using fluted filter paper (Whatman No.4). After filtering, the extract was diluted with 30 ml of purified water before being filtered through a glass microfiber filter into a clean vessel.

AflaTest[®] immune-affinity columns (IACs) were used to clean up the samples. Fifteen milliliters of the filtrate diluted extract was passed through the AflaTest[®] IAC at a rate of about 1–2 drops/second until air came through column. Then, the column was washed twice with 10 ml of purified water at a rate of about 2 drops/second; and the glass cuvette (VICAM part # 34000) was placed under AflaTest[®] IAC and 1.0 ml HPLC grade methanol was added into glass syringe barrel. Finally, AflaTest[®] IAC was eluted at a rate of 1 drop/second by passing the methanol through the column and all of the sample eluate (1.0 ml) was collected in a glass cuvette. An additional 1.0 ml of purified water was poured to eluate and analyzed by HPLC.

Reverse-phase HPLC was used to quantify AFs along with fluorescence detector followed by post column derivatization (PCD) involving bromination using a water HPLC system (pump 1525; fluorescence detector 2475; analytical column Nova-pack-C18 250 × 4.6 mm: 5 µm). Kobra cell was used and bromide added to the mobile phase to achieve PCD. Fifty microliter of diluted AF eluate was then injected into HPLC. The mobile phase included water, methanol, and acetonitrile mixture with the 600:300:200 (V/V/V) ratio. A sample was considered as positive to AF if at least one of the four types was positively observed on HPLC chromatogram reading.

The limit of detection using the protocol described above is 0.10 ppb for total aflatoxin and 0.05 ppb for B1, 0.03 ppb for B2,

0.03 ppb for G1, and 0.05 ppb for G2. The correlation coefficient (r) of 0.9951 from the linear regression equation ($Y = 0.9242X + 0.0547$) indicates that the linearity of this method is excellent. The percentage recovery from this method is greater than 85% for aflatoxin B1, B2, and G1 from 0.10 ppb to 10.0 ppb. Aflatoxin G2 recovery is greater than 55% for the 0.5 ppb–10 ppb range. The validation data from the method used further showed a very good reproducibility for total aflatoxin (ranging from 0.5 ppb to 10 ppb) with an average coefficient of variation less than 8%. For individual aflatoxin B1, B2, G1 and G2 (ranging from 0.5 ppb to 10 ppb), the average coefficient of variation is less than 12%. The method has also a very good repeatability with a coefficient of variation for total aflatoxin of 2.6% and less than 3.2% for individual aflatoxin B1 and B2.

2.3. Data analysis

Data were summarized and analyzed using Excel 2007® and Stata® version 13.0 softwares, respectively. Since the data were skewed, a log transformation was done to facilitate estimation of parameters compliant to the normal distribution. The median and the geometric mean were used to estimate the central tendency while the Chi-square test was used to test for association between hypothesized categorical risk factor and the outcome (AF presence). A logistic regression was used to determine multiple effects of predictor variables on the outcome (AF presence).

3. Result

3.1. Aflatoxin levels in raw peanuts from markets of Lusaka district

A total of 92 raw peanut samples from open markets ($n = 73$) and supermarkets ($n = 19$) were collected and analyzed for AFs presence and concentration levels. Overall, 55.4% of all samples tested positive for AF presence. The concentration levels of AF in peanuts traded from both types of markets in Lusaka ranged from 0.014 to 48.67 ppb. The median concentration of samples tested positive for AF was 0.23 ppb, and since the data were skewed, a log transformation into normal distribution was done, which gave a geometric mean $\pm$ SD of 0.43 ± 9.77 ppb. It was observed that AFB1 and AFB2 were the most common types occurring at the same frequency (Table 1). However, AFB1 had the highest concentration levels (46.6 ppb), median (0.23 ppb) and mean concentration (0.45 ± 9.41 ppb) (Table 1).

The proportion distribution of positive samples within each market type, separately, was almost the same (57.9% for the supermarkets and 54.8% for the open markets). However, there was a difference in the concentration levels between the two market types. The median concentration for AFB1 was apparently higher in the supermarkets (0.37 ppb) compared to the open markets (0.23 ppb). Although, the association between market types and presence of AFs was not statistically significant (Pearson $\chi^2 = 0.0587$, $p = 0.809$).

Out of all ($n = 92$) the samples, 6.5% ($n = 6$) (95% CI: 2.9–13.9)

and 12% ($n = 11$) (95% CI: 6.7–20.5) had AF levels above the MPLs set by the CAC and EU standards, respectively. Furthermore, of all ($n = 40$) the peanut samples from the open markets that tested positive for AF, 12.5% ($n = 5$) (95% CI: 5.1–27.4) and 25% ($n = 10$) (95% CI: 13.7–41.2) were above the MPLs set by the CAC and EU standards, respectively. On the other hand only, 9.1% ($n = 1$) (95% CI: 1.1–47.7) of all ($n = 11$) the positive peanuts samples from the supermarkets had AF levels above the MPLs for both standards. However, there was no statistical difference between the type of market and the concentration levels of AF above the MPLs standard for CAC ($p = 0.756$) and EU ($p = 0.256$).

3.2. Factors associated with levels of aflatoxin

Among all factors included in the study, the univariate analysis indicated that only peanut variety was marginally associated with the presence of aflatoxin in raw peanuts at 95% confidence level (p -value = 0.054) (Table 2).

From the three peanuts varieties mostly sold in Lusaka district's markets, *Chalimbana* (Virginia runner type) was the most susceptible variety to AF contamination (62.3% of *Chalimbana* samples were positive to AF). It was further observed that out of all ($n = 43$) the *Chalimbana* peanut variety that tested positive for AF, 13.9% ($n = 6$) and 25.6% ($n = 11$) were above the MPLs for CAC and EU standards, respectively. On the other hand, for all ($n = 4$) *Makulu red* (Virginia bunch type) and *Kadononga* ($n = 4$) peanut varieties samples that tested positives for AF, the levels were within the acceptable limits for both standards. There was an apparent difference in the levels of AFs among the three varieties, although this difference was marginally not significant at 95% confidence level (Pearson $\chi^2 = 5.8531$, p -value = 0.054). However, the difference in the levels of AFs between *Chalimbana* and *Kadononga* ($p < 0.0001$), and *Chalimbana* and *M. red* ($p < 0.0001$) were significant. However, there was no difference between *Kadononga* and *M. red* ($p = 0.543$).

3.3. Relationship between factors associated with aflatoxin presence and the likelihood of finding a contaminated sample

The logistic regression analysis revealed that aflatoxin positivity was significantly associated with the type of peanut variety, with *Chalimbana* being the most risky among the three varieties investigated. The fitted model describing this relationship is shown in Table 3 below. The Hosmer and Lemeshow test for goodness-of-fit ($\chi^2 = 0.67$; Prob $> \chi^2 = 0.9549$) indicated that the model fitted adequately the data. Based on the model, the estimated odds of a sample of *Chalimbana* peanut variety being positive to AF were 3.58 times higher (95% CI: 1.29–9.91) compared to those for *Kadononga* and *M. red* peanut varieties samples, after adjusting for the effect of storage place and the type of package. The area under the ROC indicates that the model can correctly predict up to 66.6% of the outcome.

Table 1

Summary of the proportion, mean, median and range concentration of aflatoxins in raw peanuts samples from Lusaka district's market.

Variables	Positive observations (%)	Median (ppb)	^a Mean $\pm$ SD (ppb)	Min (ppb)	Max (ppb)
AFB1	$n = 41$ (44.6)	0.23	0.45 ± 9.41	0.015	46.60
AFB2	$n = 41$ (44.6)	0.132	0.15 ± 7.87	0.006	13.17
AFG1	$n = 21$ (22.8)	0.028	0.04 ± 3.76	0.005	0.51
AFG2	$n = 7$ (7.6)	0.008	0.012 ± 2.34	0.006	0.04
AF	$n = 51$ (55.4)	0.23	0.43 ± 9.77	0.014	48.67

^a Geometric mean.

Table 2

Factors associated with aflatoxin presence in raw peanuts samples.

Variables		Proportion AF test positive (%)	P-value
Type of markets	Supermarkets	57.9	0.809
	Open Markets	54.8	
Country of origin	Zambia	56.5	0.713
	Mozambique	33.3	
Peanut variety	South Africa	50.0	0.054
	Chalimbana	62.3	
	Makuru red	44.4	
Type of packaging	Kadononga	28.6	0.788
	Opened permeable packaging	58.5	
	Opened Impermeable packaging	50.0	
	Closed impermeable packaging	51.5	
Storage place after the daily selling	Store room	50.9	0.433
	Under the raised concrete surface	68.8	
	On the selling shelves	57.9	
Duration of raw peanut on the market	Less than 15 days	53.9	0.634
	More than 15 days	59.3	

Table 3

Results of the logistic regression model.

	Odds ratio	Z	P> z	[95% conf. Interval]
Chalimbana	3.58	2.45	0.014	1.29 9.91
Storage place1	0.38	−1.79	0.073	0.13 1.09
Type of Package1	2.36	1.65	0.099	0.84 6.58
Constant	0.54	−1.12	0.263	0.18 1.59

Storage place1: Store room; Type of Package1: Permeable package and in open air.

4. Discussion

This study investigated the occurrence of AFs in raw peanuts sold in Lusaka district's markets. It further identified factors associated with increased aflatoxin presence in raw peanuts in those markets.

It was observed that most peanuts traded on Lusaka district's markets were contaminated with aflatoxin (55.4%), but the concentration levels were generally low. These results are comparable to those obtained by Kaaya, Warren, and Adipala (2000) in Uganda who reported a proportion of 50% of positives samples to AF. However, studies conducted in Western Kenya (Mutegi, Ngugi, Hendriks, & Jones, 2009) revealed levels of AF ranging from 0 to 2687.6 ppb and 0–7525.0 ppb from the households in two different districts. The high levels of AF reported in the Kenyan study could be explained by the fact that peanuts samples originated from humid agro-ecological zones which is a risk factor for the development of fungi that produce AFs (Cotty & Jaime-Garcia, 2007), and also poor storage conditions of peanuts which characterize most of the African villages (Hell & Mutegi, 2011).

The levels of AFB1, the most carcinogenic type, were detected in the range of 0.015–46.6 ppb in forty-one raw peanuts samples (44.6% of incidence) and had the highest concentration levels (46.6 ppb). This observation corroborates what was observed in similar studies conducted in Democratic Republic of Congo (DRC) (Kamika & Takoy, 2011), in Sudan (Shami Elhaj & Ahmed Altayeb, 2011), and in Malaysia (Sulaiman et al., 2007) who reported a proportion of 53%, 53.3%, and 50%, respectively. In contrast, the aforementioned studies differ by their range of concentration levels which are higher (1.5–390; 0.8–547.5; 13.47–404.00 ppb, respectively) compared to our study. Nevertheless, several studies, including those in Botswana (Siame, Mpuchane, Gashe, Allotey, & Teffera, 1998), in Hong Kong (Lund, Parker, & Gould, 2000) showed a relatively low level of contamination (0.8–16.00, 3.2–16.00 ppb, respectively) of AFB1 in peanuts, supporting the findings in our study.

Although the concentration level of AF detected was relatively low in most samples, the population of Lusaka district is not safe from the adverse effects of AFs considering the fact that peanut is among the staple food in Lusaka district (Sitko et al., 2011). Previous studies demonstrated that high intake of contaminated foodstuff by AFs even at relatively low level is harmful for human health (Shephard, 2008; Wu et al., 2013). The situation is more critical when we consider that peanuts powder is often added to maize porridge for infants because of its high protein value. Maize, another susceptible crop to AFs contamination, is consumed almost every day in Lusaka district, thus increasing the risk of double exposure to AF from both the peanut and maize source.

The geometric mean concentration levels of 0.43 ± 9.77 ppb was observed for AF. These results corroborate the findings by Ostadrahimi et al. (2014) in Iran. In a similar study conducted in DRC, Kamika and Takoy (2011) reported a high mean concentration of 205.7 and 23.37 ppb during the rainy and dry seasons, respectively. This could be attributed to the fact that the samples in that study were drawn exclusively from markets in rural area characterized by poor handling of food commodities which has been described as a factor associated with aflatoxin contamination of products (Huang, Han, Cai, Wu, & Ren, 2010; Kaaya, Harris, & Eigel, 2006).

In this study we observed low concentration levels of AFB2, AFG1 and AFG2. This corroborates what has been reported in other studies where the presence of the three types of AFs in peanuts samples were observed in low levels compared to the B1 (Huang et al., 2010; Siwela, Mukaro, & Nziramasanga, 2011).

Although the difference in the distribution of positive raw peanuts samples to AFs between the two types of markets was not statistically significant in our study, the highest level of AFs concentration was detected in samples from the supermarkets (48.67 ppb for AF, 46.6 ppb for AFB1 with a median of 0.37 ppb). One would have expected raw peanuts sold in the open markets to have the highest levels of AFs compared to the one sold in supermarkets. This might be the result of the sorting practices in most of the open markets whereby discolored, broken or shriveled nuts are continuously discarded. While in the supermarkets, once the raw peanuts are packaged, they are more likely to stay in such condition until they are sold off the shelves. Previous studies reported that the grounding sorting significantly reduces the levels of AFs in peanuts (Galvez, Francisco, Villarino, Lustre, & Resurreccion, 2003; Ndung'u et al., 2013). Furthermore, the peanuts in open markets are exposed "in the open air" so, they are continuously drying; while in supermarkets, they are mostly packed in plastics that limit loss of moisture.

In contrast, 12.5% and 25% of all the positive raw peanut samples to AF from the open markets were above the MPLs for Codex Alimentarius Standards (15 ppb) (CAC, 2014) and EU standards (4 ppb) (Wu et al., 2013), respectively. While from the supermarkets only one sample, representing (9.1%) of all the positive raw peanuts samples to AF exceeded the MPLs for both standards. This implies that in terms of peanut rejection frequency based on MPLs; this is likely to be high in peanuts traded on open markets compared to supermarkets. In a study conducted from markets in Kenya, Mutegi et al. (2013) reported a high proportion of AF contamination exceeding the CAC and the EU standards in the open markets compared to the supermarkets. These results corroborate the findings of our study. In general most supermarkets tend to have minimum standard for product purchase, and some form of inspection is conducted for product quality certification which is often absent among vendors trading on the open markets.

Further, the high proportion of AF contamination exceeding the standards set by the CAC and the EU observed in the open markets, despite the sorting that is practiced and the continuous drying effect, might be explained by several factors among them the poor handling and storage condition. In most open markets of Lusaka district, peanuts are stored crowded with other foodstuff and exposed to the insect activities. These are among factors that could increase the likelihood of crops contamination by aflatoxin (Cotty & Jaime-Garcia, 2007). Peanuts sold in the open markets are also exposed to rainwater by the fact that they are usually packed in open permeable bags and often unsheltered.

Of all factors studied, only the variety of peanuts was significantly associated with the levels of AFs in raw peanuts samples. It was observed that *Chalimbana* variety was the most susceptible to AF contamination compared to the other varieties. Previous studies have described *Chalimbana* variety (Virginia runner type) as possessing factors which facilitate its contamination to AFs. These include the long duration it takes to maturity, 150–160 days, increasing its exposure to the rainfall (Hell & Mutegi, 2011; Mukuka & Shipekesa, 2013); the extremely labour intensive it takes during harvesting by the fact that the uprooting process require intensive digging and the pegs are thinner and weaker which means that pods often become separated from the plant at harvest (Ross and de Klerk, 2012). This extends the harvest period and the field exposure of the nuts to AFs after the physiological maturity (Guo, Chen, Lee, & Scully, 2008).

Furthermore, the runner type does not resist drought and disease as compare to the bunch type (Ross and de Klerk, 2012). Okello, Kaaya, Bisikwa, Were, and Oloka (2010) reported that excessive drought causes strains on pods and testas thus providing entry points for infection by fungi. It is also hypothesized that big size of *Chalimbana* compared to other varieties investigated might play also a role in the vulnerability of this variety to AF contamination. Being relatively large in size implies that it is likely not to dry fast after harvest, thus prolonging the availability water activity (a_w) required for fungal growth.

5. Conclusion

This study has revealed the wide occurrence of AFs in raw peanuts from Lusaka district's markets. Although the supermarkets have better infrastructures compared to the open markets, our study did not find a significant difference on the proportion of contaminated raw peanuts with AFs between the two markets. However, open markets had high proportion of samples with AF concentration levels above the CAC and the EU standards; while, the highest concentrations of AFs recorded in raw peanuts were in the samples from the supermarkets.

The high incidence of positive raw peanuts to AF exceeding the

MPLs for CAC and the EU standards observed in both supermarkets and open markets constitutes a health hazard for the population of Lusaka district. Further, the variety of peanut plays a significant role in the contamination of peanuts to AFs. In this case, *Chalimbana* variety was found to be the most at risk of contamination to AFs. However, our study did not explore all key factors which could promote mould growth and AF production in peanuts such as the moisture content, the levels of humidity, and crops damage.

A market vendor's awareness through education campaigns on practices which reduce the AF contamination in peanuts should be conducted. Further, a human exposure assessment to AFs through consumption of peanuts need to be carried out in order to determine the public health impact caused by AFs to the Zambian population.

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