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RESEARCH ARTICLE

Aflatoxin risk management in commercial groundnut products in Malawi (Sub-Saharan Africa): a call for a more socially responsible industry

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Abstract This study was performed as a follow-up to a study from 2013, to assess the impact of management interventions on aflatoxin incidence and levels in commercial groundnut products in Malawi. Sixty-seven samples of commercial groundnut products were analyzed for aflatoxin using a fluorometric method. Total aflatoxin levels ranged from 1.5 to 1200 μg/kg in raw groundnuts and 83–820 μg/kg in groundnut flour from vendors. In branded groundnut flour and peanut butter from supermarkets, aflatoxin levels ranged from 13 to 670 μg/kg and 1.3 to 180 μg/kg, respectively. About 93, 88, 78 and 72% of the samples analyzed contained aflatoxin levels above regulatory limit used in Malawi (3 μg/kg), EU (4 μg/kg), most developing countries (10 μg/kg), and the USA (20 μg/kg), respectively. Despite much effort, aflatoxin levels remain persistently high in commercial groundnut. Considering the difficulty of achieving an efficient government regulation system due to resource constraint, the authors recommend the promotion of a socially responsible groundnut processing industry that has consumer welfare as its central feature.

Keywords Aflatoxin · Commercial groundnut products · Malawi · Risk management

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1 Introduction

Groundnut (peanut) is one of the most important crops grown in Africa because it provides both dietary nutrients and income to the majority of the population (Diop et al. 2004; Gowda et al. 2009). Groundnuts are rich in digestible protein (25–34%), vegetable oil (44–56%), vitamins and minerals, which are of particular importance in human nutrition especially in the developing world (Savage and Keenan 1994). Groundnuts are consumed in a variety of snacks, and they are a major constituent in ready-to-use therapeutic food (RUFT), one of the most effective home-based nutritional therapies for children and HIV/AIDS patients, particularly in the developing world (Ndekha et al. 2005; Isanga and Zhang 2007; Sunguya et al. 2012; Arya et al. 2016). In Malawi, groundnuts are an important source of income (Diop et al. 2004; Simtowe et al. 2010; Derlagen and Phiri 2012).

However, the quality of groundnuts is often compromised by aflatoxin contamination (Ezekiel et al. 2012; Mutegi et al. 2013; Watson et al. 2014; Njoroge et al. 2016, 2017; Mohammed et al. 2016). Aflatoxins are immunosuppressive, teratogenic, mutagenic, carcinogenic, genotoxic and hepatotoxic (Wong and Hsieh 1976; Williams et al. 2004; Oswald et al. 2005; El-Nahla et al. 2013) to humans and animals, depending on the duration and level of exposure. Chronic exposure to aflatoxins has been reported to contribute to malnutrition and growth impairment in children (Gong et al. 2004; Magoha et al. 2014; Hernandez-Vargas et al. 2015; Shirima et al. 2015). Also, increasing evidence suggests that aflatoxins accelerate the rate of progression from HIV infection to AIDS (Jiang et al. 2008; Jolly et al. 2013; Jolly 2014).

Consequently, most governments have regulations, which stipulate maximum levels (MLs) of allowable aflatoxins in food to reduce aflatoxin exposure (FAO 2004). However, in many developing countries, law enforcement is a challenge and aflatoxin awareness is low among the majority of the consumers. Therefore, the availability of regulations does not guarantee reduction in the risk of aflatoxin exposure (Kaaya et al. 2006; James et al. 2007; Jolly et al. 2009; Ilesanmi and Ilesanmi 2011; Matumba et al. 2015b).

In Malawi, aflatoxin contamination of foods, particularly groundnuts, have received increasing attention in recent years among various government agencies, non-governmental organizations and development partners (Rios et al. 2013; Edelman and Aberman 2015). This drive is among others instigated by market surveys that report widespread aflatoxin contamination (e.g. Monyo et al. 2012; Matumba et al. 2014, 2015a). However, there has not been any follow-up study to assess if the efforts by these stakeholders (partners) have resulted in significant reduction in aflatoxin in commercial groundnut products. In this context, this contribution not only provides a record of the present aflatoxin contamination of commercial products in Malawi, but also assesses the variation of the aflatoxin contamination over a period of 4 years. The findings of this study have the potential to influence policy direction and enhance vigilance in aflatoxin risk management, especially in the sub-Saharan region.

2 Materials and methods

A total of 67 samples of commercial groundnut products were evaluated. The samples were purchased from vendors and supermarkets in Lilongwe city, Malawi, in January and February 2017. The products included 15 packs of groundnut flour and 28 1-kg samples of raw shelled groundnuts purchased from vendors. These were randomly sampled from 4 townships that were purposively selected to provide a good geographical and socio-economic coverage of the city. Products from the supermarkets included 13 different containers of peanut butters and 11 packets of groundnuts flour. The samples were analyzed for aflatoxins as described below. The results of this study were compared with those found in a similar study of 2013. This was done to assess the impact of various aflatoxin management interventions over a period of 4 years in Malawi.

2.1 Analytical reagents and equipment

AflaTest columns, disposable plastic pipettes, VICAM fluted filter paper (24 cm diameter), microfiber filters, 1.5 μm (11 cm diameter AflaTest developer, mycotoxin calibration standards, disposable cuvettes, 6-position pump stand with an air pump and VICAM Series-4EX Fluorometer were obtained from VICAM (Milford, MA, USA). Methanol and non-iodized salt, NaCl, were supplied by Merck (Darmstadt, Germany). 5.0 μg/mL total aflatoxins (AFB1/AFB2/AFG1/AFG2; 4/1/4/1) for recovery studies were purchased from Trilogy Analytical Laboratory (Washington, MO, USA). After reconstitution in 10 mL acetonitrile, the stock standard solutions were stored at -20 °C. Double distilled water was used in the analysis.

2.2 Extraction, clean-up and aflatoxin determination

Extraction and clean-up of aflatoxin from peanut samples was done using a modified version of the manufacturer's instruction for the Aflatest® immuno-affinity procedures for nuts (VICAM 2014). To a portion (25 g) of the finely ground groundnut sample, 5 g of NaCl was added and the mixture extracted with 125 mL of methanol/water (60:40, v/v), blended at high speed for 2 min. The extract was filtered, the filtrate diluted (1:1) with water and then was filtered again through a glass-fibre filter. A 10 mL (1 g sample equivalent) of the diluent was passed through Aflatest® affinity column. The columns were then washed with 10 mL of water to remove intrinsic compounds present in the groundnut sample. Finally, the aflatoxins were selectively eluted with 1 mL of 100% methanol followed by addition of 1 mL of Aflatest developer. The total volume of the eluent (2 mL) was mixed using a vortex mixer for 30 s after which the sub-sample was analyzed using a calibrated fluorometer. To validate the method for the production of accurate results and verify its effectiveness, blank samples of groundnut flour were spiked at 20 μg/kg (total aflatoxins, AFB1/AFB2/AFG1/AFG2; 4/1/4/1) and the mean recovery rates were determined by repeating the procedure three times. Additionally, analytical proficiency was verified through regular participation in FAO-Texas A&M University (TAMU) Aflatoxin Proficiency Testing and Control in Africa (APTECA), Texas A&M AgriLife Research, Texas A&M) (APTECA 2017) and the *Z*-score was always in the satisfactory range (between 1 and +1).

2.3 Precautions and safety consideration

Aflatoxins are carcinogenic compounds; consequently, disposable latex gloves were worn at all times during handling of solutions, extracts and samples only in properly ventilated hoods. Aflatoxin residues on laboratory ware, pipette tips and kit components were destroyed using 10% solution of household bleach before discarding. Accidental spills of aflatoxins were swabbed with 5% NaOCl bleach.

2.4 Statistical analyses

Aflatoxin data were log-transformed ($\log X + 1$) for statistical analysis due to normality assumption violation. The resultant transformed data had equal variance and were normally distributed. This was established through Levene's test and normal probability plots, respectively (Kuehl 2000). The difference between means was assessed by analysis of variance (ANOVA). Aflatoxin contamination results were expressed as mean ± standard deviation (SD). Data were analyzed using IBM SPSS Statistics, version 20 (IBM Inc). The level of confidence required for significance was set at $p \leq 0.05$.

3 Results

3.1 Analytical method performance

The mean recovery was 97 ± 1%. Therefore, the analytical method was satisfactory according to European Commission (EC) regulations (EC 2006). The relative standard deviations (RSD) of the recoveries was 3.0% which demonstrated that the method was well under control during the analytical session. Results are reported based on the limit of detection (LOD) of 1 μg/kg.

3.2 Incidence and level of aflatoxins in commercial groundnuts products

Aflatoxins were detected in all (67) samples. The levels of total aflatoxin ranged from the LOD up to 180 μg/kg (Mean ± SD; 77 ± 59 μg/kg) in peanut butter samples from the supermarkets, 670 μg/kg (279 ± 218 μg/kg) in branded groundnut flours from supermarkets, 820 μg/kg (187 ± 260 μg/kg) in groundnuts flours from vendors and 1200 μg/kg (182 ± 276 μg/kg) in raw groundnuts (Fig. 1). The aflatoxin levels in the four different products overlapped greatly. Consequently, there was no statistical mean differences among the products.

Nearly all (93%) of samples contained aflatoxin levels above the regulatory limit (3 μg/kg) for commercial food products in Malawi (MS 213:1990; MS 554:1996). The majority of the samples were above

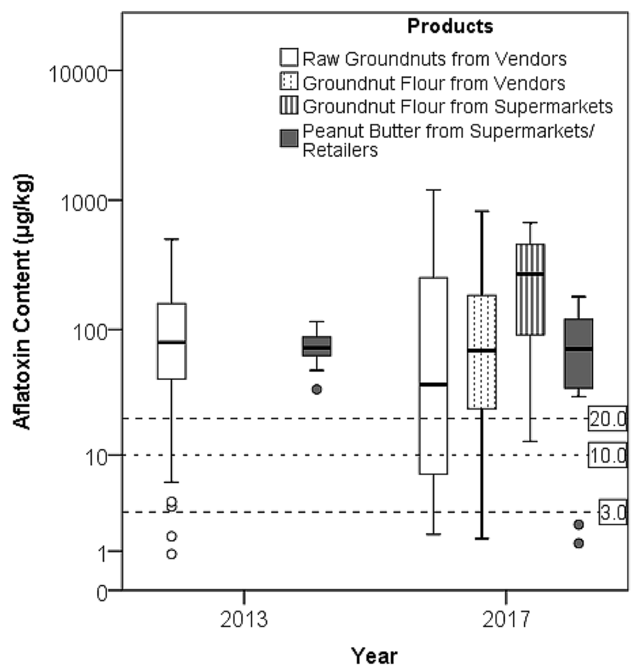

Fig. 1 Distribution of aflatoxin in raw groundnuts (n = 28) and groundnut flour (n = 15) purchased from vendors; and groundnut flours (n = 11) and peanut butters (n = 13) purchased from supermarkets in Lilongwe city in 2017 and groundnut products analyzed in 2013 (Matumba et al. 2015a). Boxes represent the interquartile range that contains 50% of values (range from the 25th to the 75th percentile). The line across the box indicates the median. The whiskers represent maximum and minimum values, excluding outliers [indicated by circles, at least 1.5 times the interquartile range but less than 3 times (i.e., 1.5 box lengths from the upper or lower edge of the box)]. Reference lines (dotted) indicate the maximum level set for total aflatoxin (3 μg/kg) in groundnuts for human in Malawi (Malawi Standards Board 1990, 1996); median for total of aflatoxins limits used worldwide (10 μg/kg) (FAO 2004) and total aflatoxin limit for human consumption enforced by USFDA

both the median for total of aflatoxins limits used worldwide (10 µg/kg; FAO 2004) and total aflatoxin limit for human consumption (20 µg/kg) enforced by the United States Food and Drug Administration. Comparatively, higher percentages of nonconformities to these guidelines were observed in samples from supermarkets than those purchased from vendors (Table 1 and Fig. 1), although nearly all (except one) supermarket brands carried certification marks of the Malawi Standards.

Compared with the results of the 2013 study, there is no significant difference between aflatoxin levels in commercial groundnut products (raw groundnut and peanut butter) that were sampled in 2013 and those sampled in 2017 (Fig. 1). In the raw groundnut samples that were analysed in 2013, aflatoxin levels ranged from 0.9 to 501.0 µg/kg (mean: 122.3 µg/kg; median: 79.3 µg/kg) whereas aflatoxin content in processed peanut butter ranged from 34.2 to 115.6 µg/kg (mean: 76.1 µg/kg; median: 72.0 µg/kg) (Matumba et al. 2014, 2015a).

4 Discussion

From the present study, it is clear that aflatoxin contamination in groundnuts and groundnut-based products is persistent in Malawi. This is an indication that efforts to reduce aflatoxin exposure have not achieved the desired impact of significant reductions in aflatoxin contamination on the market. Much of the failure is attributable to inefficient food safety system in Malawi. In particular, this points to failures that are related to the regulatory and monitoring framework in Malawi. Most of the non-complying groundnut products found in supermarkets had Malawi Standard (MS) certification mark, which indicates that the products meet the respective MS requirements [MBS act of 1972, Cap 51:02, section 21(3)]. Analysis of the results and the regulatory system for food safety in Malawi provides more insights into the aspects that contribute to the failure of the system and are discussed below.

4.1 Institutional arrangement and analytical capacity

A potential weak point of the Malawi's food safety system is partly because the mandate of surveillance and enforcement lies in multiple regulatory agencies, which contributes to the confusion over who is responsible. In Malawi, the Ministry of Health, Malawi Bureau of Standards (MBS) and the Ministry of Local Government have mandates to enforce regulations for ensuring food safety. The MBS plays a major role in the development of Malawi Standards (MS), certification of locally manufactured products, regulatory monitoring of the quality of products in retail and supermarkets and quality control for imports (MBS Act of 1972). The relevant standards for regulation of aflatoxins in groundnuts are mandatory (MS 213:1990; MS 554:1996). On the other hand, control of the quality of food products sold by vendors in the local market places is primarily a shared responsibility of Ministries of Health and Local Government (Public Health Act of 1969).

Table 1 Number (percentage) of samples with total aflatoxin ($AFB_1 + AFB_2 + AFG_1 + AFG_2$) level greater than various regulatory limits found on the market in Lilongwe in 2017

Total aflatoxin regulatory limit (µg/kg)	Number of samples with total aflatoxins greater than regulatory limit				
	Vendors		Supermarket		Overall ($N = 67$)
	Raw groundnuts ($N = 28$)	Groundnut flours ($N = 15$)	Groundnut flours (branded) ($N = 11$)	Peanut butter ($N = 13$)	
3[a]	26 (93)[e]	14 (93)	11 (100)	11 (85)	62 (93)
4[b]	24 (86)	13 (87)	11 (100)	11 (85)	59 (88)
10[c]	17 (61)	13 (87)	11 (100)	11 (85)	52 (78)
20[d]	16 (57)	11 (73)	10 (91)	11 (85)	48 (72)

[a] Total aflatoxin limit for commercial food products guided by Malawi Bureau of Standards (Malawi Standards Board 1990, 1996)

[b] Total aflatoxin limit for ready to eat groundnuts enforced by EU (EC 2010)

[c] Median limit in food currently established in legislations worldwide (FAO 2004)

[d] Total aflatoxin limit for human consumption enforced by USFDA

[e] Figures in parentheses are cumulative percentages of the total population of the respective columns

Among the regulators mentioned above, only the MBS is currently involved in testing for aflatoxins. Moreover, quality control of foods from vendors' merchandise is inherently complex due to high numbers of vendors selling small sizes of lots and the difficulty of tracing production chains. In this case, effective preventive measures can only be achieved by entrusting food producers with primary responsibilities for food safety and the government regulators auditing the performance of the food safety system (FAO and WHO 2003).

Poor regulatory monitoring may also be attributable to a low priority and emphasis that it put on aflatoxin monitoring. In public health, Malawi prioritizes monitoring of micronutrients in fortified foods intended to reduce the incidence of nutrition deficiency diseases and improve cognitive ability in under-five children. The Ministry of Health uses its inspectors and health surveillance assistants to monitor imports, the retail market and households and they also conduct periodical sentinel surveys, usually with funding from UNICEF. This is because, in Malawi, micronutrient deficiency is attributed to low dietary intake of micronutrients. However, aflatoxins are known to depress immunity and affect nutrient absorption and utilization (Cheeke and Shull 1985; Fink-Gremmels 2008; Gong et al. 2008; Jiang et al. 2008; Jolly et al. 2013). The persistent occurrence of aflatoxins in groundnuts may worsen the prevalence rates of stunting among children, which is estimated at 50% in Malawi (ORC Macro 2006) and further compromise health of those living with HIV/AIDS. Unfortunately, the majority of consumers are also not aware of the adverse health effects of exposure to aflatoxins and therefore they cannot demand aflatoxin free foodstuffs from the market (Matumba et al. 2016).

4.2 Poverty and lack of awareness among consumers

Sorting is one of the most viable ways to eliminate aflatoxins from the food value chain (Matumba et al. 2015b). However, most often food safety takes second place to food and economic security and the grade-outs are not taken out of the food value chain. Most African countries rely heavily on exports of agricultural commodities for a large share of their export revenues (Diao et al. 2007). Regarding groundnuts, this entails sorting the groundnuts to meet stringent aflatoxin regulations set by the export market, which leads to concentration of mycotoxins in food for locals (FAO 2004; Matumba et al. 2015a). The sale of raw groundnut grade-outs from the export chain was previously highlighted as one way of concentrating aflatoxin in local food chains (Matumba et al. 2015a).

In the present survey, the analysis of variance (ANOVA) did not show a significant influence of location on mean aflatoxin levels in the groundnut products. However, it was observed that majority of the raw groundnut samples from one township had remarkably high proportions of splits (30 ± 20%). Further investigations indicate that these groundnuts (with a high proportion of splits) were grade-outs from a neighboring company which exports groundnuts to stringent markets overseas. Further, it was observed that often the vendors were selling more than one groundnut product and pricing of the nuts was somehow dependent on the proportion of splits and mold fractions. The price of the raw groundnuts ranged from US$0.64 in groundnuts with greater proportion to US$1.28 in groundnuts with intact kernels (mean = US$1.05).

Groundnut kernels that are broken (splits), shriveled, undersized, insect-damaged or mouldy are at higher risk for aflatoxin contamination (Sellschop et al. 1965; Whitaker et al. 1999, 2005; Ginting and Rahmianna 2015). The presence of groundnut grade-outs on the market intended for human consumption further affirms that a significant fraction of the Malawian population is not aware of health risks associated with mycotoxin exposure (Matumba et al. 2016). Therefore, while it is necessary to export food commodities to quality-stringent high-value markets for the country's economic growth, there is a need for the government to prioritize food safety of its citizens by regulating the disposal and use of toxic by-products. Compliance with such regulations would be promoted if the processors are encouraged to divert the grade-outs toward economically feasible alternative processing chains such edible oil production owing to low transfer rates of aflatoxins due to their high polarity and lipophobicity (Mahoney and Molyneux 2010).

5 Conclusion and future perceptive

The present findings confirm the general status in many sub-Saharan African countries where food safety regulations in are in place, but most countries lack the capacity for effective implementation (Njoroge et al. 2016, 2017; Matumba et al. 2017). Rules that are not enforced are not just useless but they are dangerous, for they give the illusion of order. While it is important to develop a new Food Safety Act which would provide a firm and clear legislative foundation for the food control system and ensure implementation of such, a value chain management approach is necessary. If food processors and operators could control the levels of aflatoxins in their raw material, farmers would be forced to follow measures that reduce aflatoxin contamination.

Future aflatoxin control and mitigation efforts, in addition to raising public's awareness on the issue, should also prioritize the creation of a socially responsible food industry practice that has consumer welfare as its central feature. In addition, there is need to mainstream food safety issues into the programs for improving nutrition. A well-grounded self-regulatory system by producers/operators would not only ensure consumer safety but could ultimately conserve the already constrained government resources that would be spent on an expensive fruitless adversarial government regulation.

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Compliance with ethical standards

Conflict of interest We declare that we have no conflict of interest.

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