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Incidence of aflatoxin in peanuts (*Arachis hypogaea* Linnaeus) from markets in Western, Nyanza and Nairobi Provinces of Kenya and related market traits

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ABSTRACT

Fungal contaminants in major food staples in Kenya have negatively impacted food security. The study sought to investigate peanut market characteristics and their association with levels of aflatoxin in peanuts from Western, Nyanza and Nairobi Provinces of Kenya. Data were collected from 1263 vendors in various market outlets using a structured questionnaire, and peanuts and peanut products from each vendor were sampled and analyzed for aflatoxin levels. Thirty seven per cent of the samples exceeded the 10 μg/kg regulatory limit for aflatoxin levels set by the Kenya Bureau of Standards (KEBS). Raw podded peanuts had the lowest ($\chi^2 = 167.78$; $P < 0.001$) levels of aflatoxin, with 96% having levels of less than 4 μg/kg and only 4% having more than 10 μg/kg. The most aflatoxin-contaminated products were peanut butter and spoilt peanuts, with 69% and 75% respectively, exceeding 10 μg/kg. A large proportion of peanuts in the country (44%) were traded through informal open air markets; 71.8% of products from supermarkets were safe according to KEBS and the EU regulatory limits, while only 52% from informal markets met this threshold ($\chi^2 = 95.13$; $P < 0.001$). Packaging material significantly ($\chi^2 = 73.89$; $P < 0.001$) influenced the amount of aflatoxin in the product, with the majority (68%) of peanut samples that were stored in plastic jars having >10 μg/kg of aflatoxin. Over 70% of all storage structures were poorly ventilated and dusty. Sorting comprised 53% of the various crop protection measures used by traders post-harvest. To reduce aflatoxin exposure to consumers, set standards need to be complemented by strict monitoring systems and education of producers, processors and consumers in crop commodities other than maize, which has received the most attention in Kenya. Alternative uses of contaminated produce need to be explored.

1. Introduction

Food safety is a vital gauge for food security in sub-Saharan Africa, where major food losses, health challenges and human fatalities have stemmed from contamination of key staples by fungal pathogens (Gong et al., 2002; Lewis et al., 2005). In Kenya, most efforts have been focused on maize, due to its significance as a staple and the chronology of acute incidences of aflatoxicosis (Lewis et al., 2005; Shephard, 2003). Other highly predisposed crop commodities in the region such as peanuts (*Arachis hypogaea* Linnaeus) have received little attention regarding the extent of contamination and related health and trade impact.

Peanuts are mainly cultivated in western Kenya but are traded and consumed extensively in the country (Mutegi et al., 2009). Production in Kenya is almost entirely by small scale farmers (Mutegi et al., 2009) under rain-fed agriculture. A high value crop of high nutritive content makes peanut growing a beneficial enterprise for rural farmers (Kipkoech et al., 2007), especially from the main growing regions of western Kenya. However, productivity has been declining over the years, due to unreliable rainfall, lack of high yielding disease tolerant varieties, poor crop management practices and lack of institutional support (Bucheyeki et al., 2008; Okoko et al., 1999, 2010).

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Areas in Nyanza province, where peanut is an integral part of the diet, have been shown to have high levels of malnutrition and nutritional disorders that have been linked to aflatoxin exposure (Okoth and Ohingo, 2004). Peanut is also used as a constituent of a gruel that is used as a weaning food for children in Kenya and such gruels have been found to be suitable substrates for mold growth (Okoth and Ohingo, 2004). The susceptibility of peanuts to infection with aflatoxin producing fungi has been noted elsewhere (Baozhu et al., 2009) and high levels of aflatoxin have been recorded in the nuts (Soler et al., 2010; Mphande et al., 2004). Bankole and Eseigbe (2004) have also warned that the regular use of dry roasted peanuts from Nigerian street vendors, markets and retail outlets was a potential health hazard, due to the levels of aflatoxin recovered from the nuts.

Limits for aflatoxin in food products in Kenya are 10 μg/kg total aflatoxin and 5 μg/kg aflatoxin B1 (AFB1) in peanuts and other food grains (Kenya Bureau of Standards, 2007). However, the high cost of testing discourages the majority of the farmers, processors and traders from testing their products. This setback, in the absence of adequate knowledge, is further compounded by the reluctance of consumers to pay the extra cost of a tested product, when there is a readily available alternative.

In Kenya, institutional efforts to address aflatoxin contamination in food crops have been initiated, albeit with the majority of efforts targeting maize. These include development of varieties that are tolerant to aflatoxin producing fungi, establishment of baseline data to identify contamination risk (Gachomo et al., 2004; Mutegi et al., 2009), identifying the role of peanut based diets on risk of aflatoxin exposure and human health (Okoth and Ohingo, 2004), improving post-harvest practices and sensitization.

Although increased levels of aflatoxin contamination in post-harvest peanut samples have been reported (Kaaya et al., 2006; Kladpan et al., 2004), there is little information on aflatoxin contamination of peanuts at market level in Kenya. Such information would inform processors, traders and farmers on the importance of implementing management practices to reduce contamination (Mutegi et al., 2010), improve marketing potential and price for their peanuts and create consumer demand for safe products (Boakye-Yiadom, 2003). The information would be essential in identifying and targeting effective strategies for aflatoxin management throughout the peanut value chain. The information would also be used as basis for reviewing existing regulatory standards for aflatoxin and assessing the impact of increased food safety stringency measures on food availability and trade.

This study therefore: i) characterized peanut market outlets in Nairobi, Western and Nyanza Provinces of Kenya, ii) established the incidence and contamination levels of aflatoxin in peanut products from major markets in Kenya, iii) determined the effect of peanut market practices on the levels of aflatoxin in peanuts from Kenyan markets, and iv) studied the effect of lowering regulatory levels for aflatoxin in peanut products in Kenya on trade and availability for human consumption.

2. Materials and methods

2.1. Study sites and their rationale

The study was conducted in three provinces in Kenya namely Nairobi, Western (Busia District) and Nyanza (Homa Bay, Kisii Central, Rachuonyo and Kisumu East Districts) (Figs. 1–3). Busia District is a major peanut producer and has several market outlets for peanuts. Additionally, the district has a border point with Uganda, another major peanut producer, which is characterized by a thriving cross-border trade. Nyanza province is also a leading producer of peanuts (Anonymous, 2004) and has several peanut processors as well as a high demand for peanut products. Nairobi is a major market outlet of peanuts and peanut products sourced from within Kenya and other countries, and has both large and small scale peanut processing enterprises.

2.2. Field survey and sample collection

A pre-testing exercise was carried out in the Nairobi region involving 50 vendors, 28 and 22 from Nairobi North and Nairobi South districts, respectively. Information gathered was used to design a structured questionnaire. Participants in the survey were identified through purposeful sampling, focusing on vendors who were trading in peanuts. The questionnaire addressed practices that were directly or indirectly related to either mould or aflatoxin contamination of peanuts. Data collected included information on demographics (gender, age and educational level) of the vendor; peanut products (podded raw kernels, shelled raw kernels, roasted kernels, peanut butter, boiled kernels, fried kernels, or spoilt kernels[1]) in the market; packaging material (jute bags, propylene bags, metal tins, PVC bags, paper, plastic jars, plastic basins, or reeded baskets) for peanut products in the market; sources of peanuts (own harvest, bought locally or imported from neighboring countries) traded; post-harvest crop protection method used by peanut vendors (chemical, sieving, sorting, tumbling, drying, none); type of peanut market outlet (hawking, informal market structures, formal market structures, stockists,[2] or supermarkets). Other data recorded were the state of the marketing structures (describing the condition of the roofing material, walls and floors, if any, and ventilation). A total of 1263 vendors were interviewed, and a representative peanut or peanut product sample as described by Whitaker (2006) was taken from each interviewee for aflatoxin analysis.

2.3. Aflatoxin analysis

From each vendor, a representative sample of whole nuts (0.5 kg) was collected for aflatoxin analysis. In instances where the peanuts were already packaged and sealed, at least 400 g of the product, either as a single or several packets depending on the quantity in each packet, was purchased for analysis. In cases where podded samples were collected, shelling was done manually. The samples were mixed thoroughly and ground in the laboratory using a dry mill kitchen grinder (Kanchan Multipurpose Kitchen Machine, Kanchan International Limited, Mumbai, India). In cases where peanut butter paste was sampled, no grinding was needed.

A 200 g sub-sample was drawn from each 500 (or 400) g sample and divided into two equal portions. The powder (or peanut paste) was triturated in a blender in 70% methanol (70 ml absolute methanol in 30 ml distilled water, v/v) containing 0.5% potassium chloride (w/v) until thoroughly mixed. The extract was transferred to a conical flask and shaken for 30 min at 300 rpm. The extract was then filtered through Whatman No. 41 filter paper and diluted 1:10 in phosphate buffered saline containing 500 μl/l Tween-20 (PBS-Tween) and analyzed for aflatoxin contamination using Indirect Competitive Enzyme-Linked Immunosorbent Assay (ELISA) as described by Waliyar et al. (2005).

[1] This category defines nuts considered unwholesome after sorting is done, and are sold in the market at a lower price. They are characterized by broken, moldy, discolored and shriveled kernels.

[2] Stockists: these were considered as those traders with formal structures that buy peanut in bulk and resell it to processors or smaller scale traders.

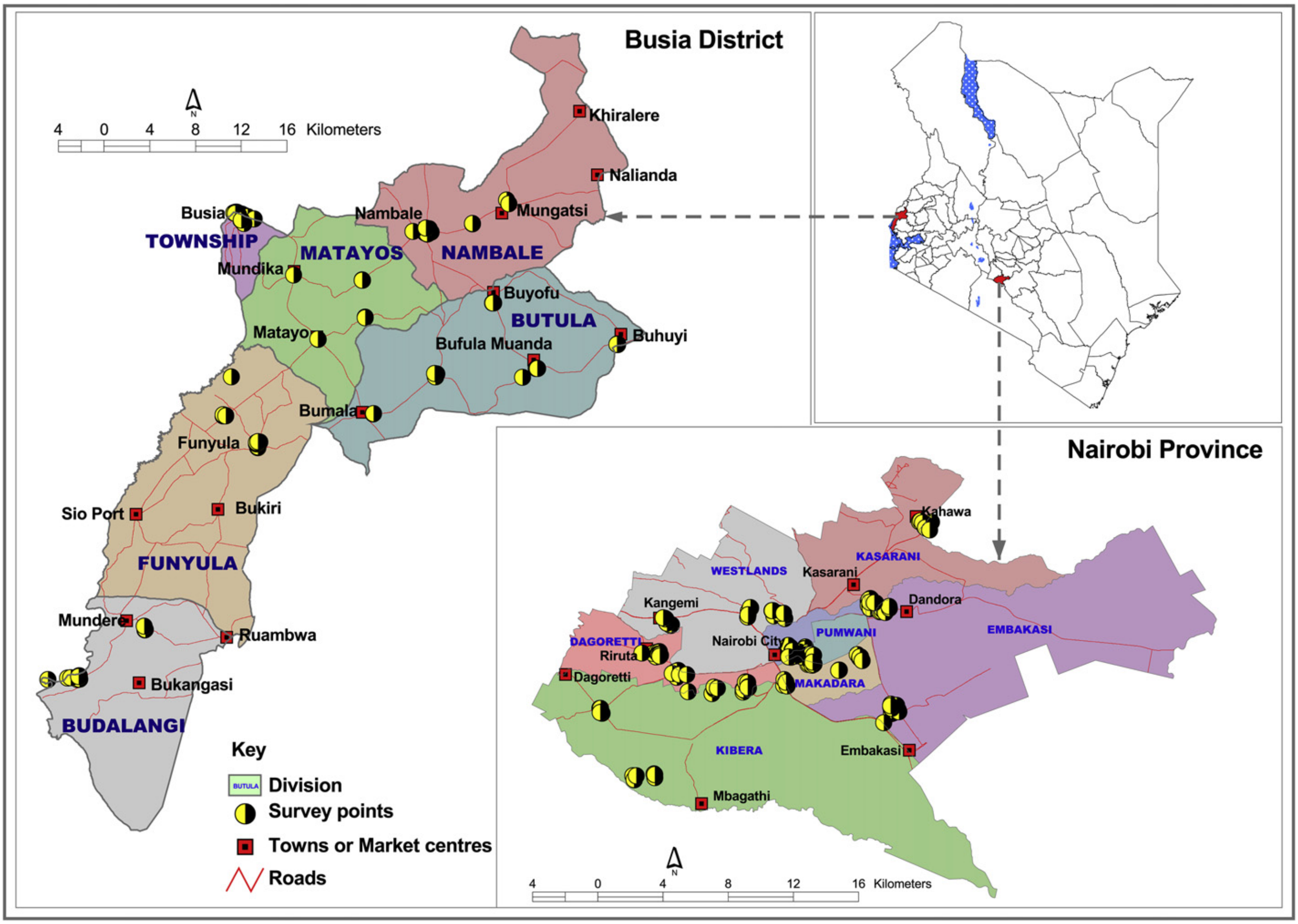

Fig. 1. Peanut sampling areas within Nairobi Province and the Busia district of Western Province. Some sampling points overlap on the map.

2.4. Moisture determination

Moisture content of peanut samples was determined using the oven drying method. Whole kernel samples were ground using a kitchen blender (Senator mixer grinder, Amargum Overseas PVT Ltd, India) for 1 min. Ten grams of the ground peanut sample were weighed together with aluminum foil and dried at 105 °C overnight in an oven (Memmert ULM 500 Schutzart oven, Schwabach, Germany). The net weight of the dried sample plus foil was determined after drying. Percentage moisture content was calculated as the difference between final and original weight divided by original weight of sample, and multiplied by 100. Each sample was replicated thrice.

2.5. Data analyses

Samples were grouped into three categories based on their aflatoxin content: samples with: ≤4 μg/kg, >4 μg/kg to ≤10 μg/kg, and >10 μg/kg. The ≤4 μg/kg threshold represents the European Union (EU) regulatory limit for total aflatoxin; peanuts in the second category would be rejected in the European Union but accepted under the Kenya Bureau of Standards (KEBS) limits, while nuts in the third category would be rejected both under the KEBS and EU standards. Frequency data was used to describe traders based on the various market attributes evaluated. Categorical data analysis by means of contingency tables was used to study associations among various market attributes as well as the relationship between these attributes and aflatoxin levels. Data was analyzed with Genstat Discovery 2 (Vers. 9, Lawes Agricultural Trust, Rothamsted Experimental Station 2006).

To study implications of increasing stringency of tolerance levels from the previous 20 μg/kg to the present 10 μg/kg, samples were grouped into a further three categories; 4–20 μg/kg, >10 to ≤ 20 μg/kg and >20 μg/kg; the first category containing samples that would be rejected under the EU regulations but accepted under the previous KEBS regulatory limits; the second category containing samples that would be rejected under the current KEBS regulation but accepeted under the previous KEBS regulation the last category containing samples that would always have been rejected. Percent frequencies in these groups were then compared with percent frequencies of samples grouped using EU and current KEBS regulatory limits. Thereafter, categorical data analysis by means of contingency tables was used to assess whether altering the tolerance levels by KEBS from 20 μg/kg to 10 μg/kg total aflatoxin would have any effect on food availability. Loss of tradable shelled peanuts in Kenya as a result of revision of the KEBS standards was calculated based on annual peanut production in the country, estimated at 19,000 tonnes (FAOSTAT, 2012).

3. Results

3.1. Demographics of peanut vendors

Three quarters of peanut marketers were female, with only 25% being male. The majority (59%) of traders had either basic primary

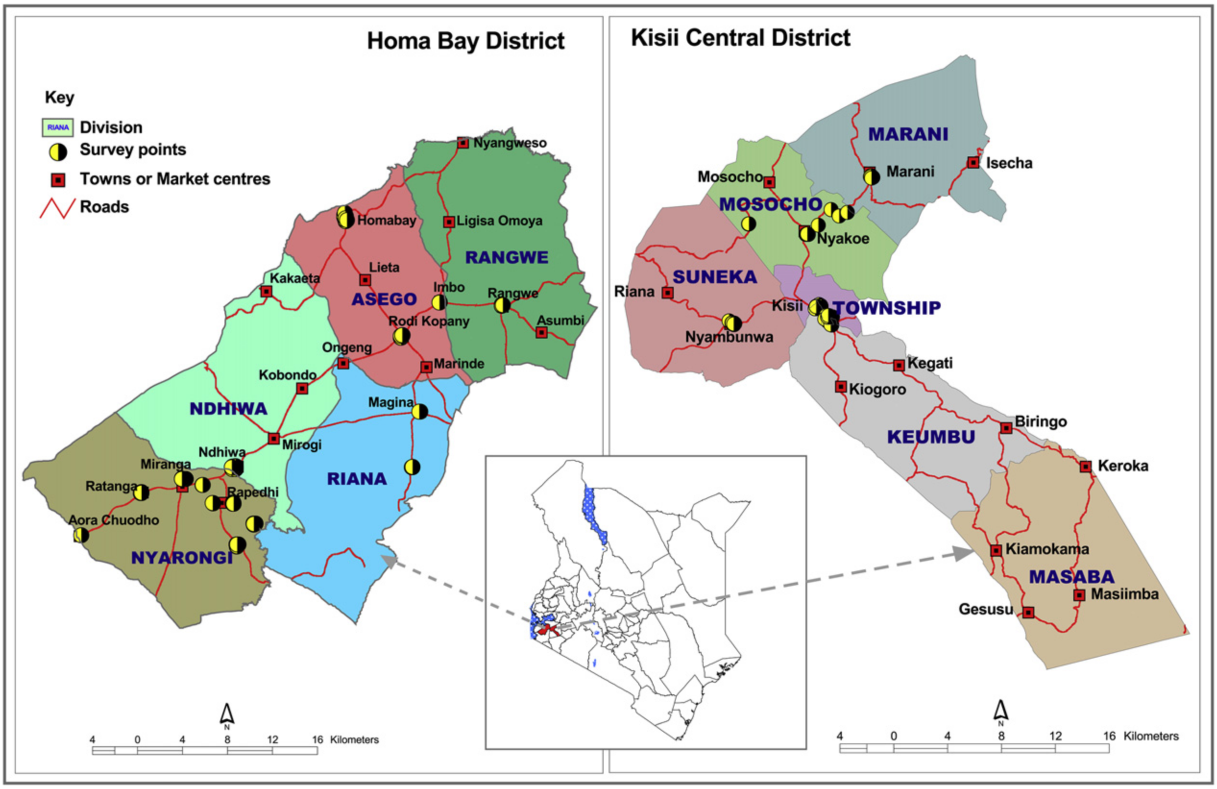

Fig. 2. Peanut sampling areas within Homa Bay and Kisii Central districts of Nyanza province. Some sampling points overlap on the map.

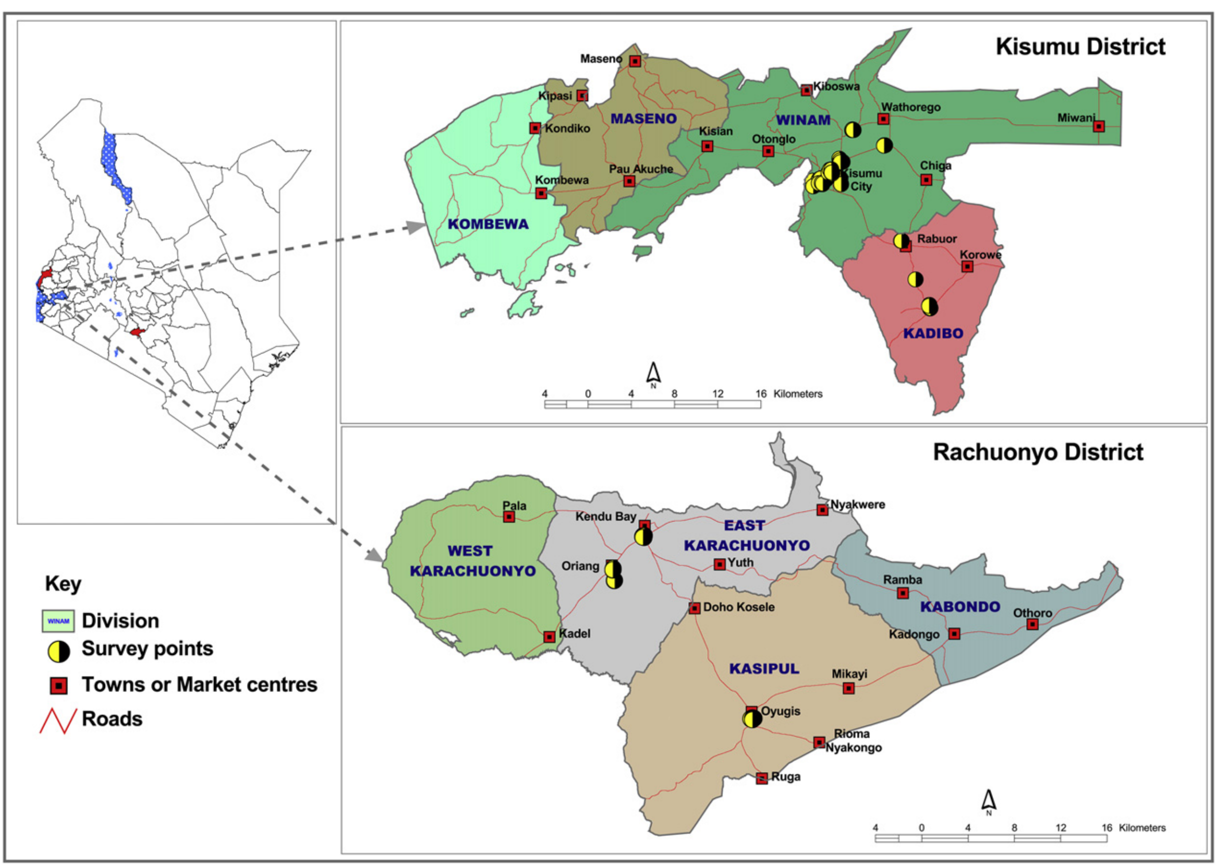

Fig. 3. Peanut sampling areas within Kisumu and Rachuonyo districts of Nyanza province. Some sampling points overlap on the map.

Table 1
Demographics of peanut vendors in market outlets in Nairobi, Western and Nyanza provinces of Kenya.

Region	Sex		Age group [years]			Education level				Total [n][b]
	Male	Female	<18	18–35	>35	None[a]	Primary	Secondary	Tertiary	
Nairobi	150[c]	214	6	253	105	13	103	161	87	364
Nyanza	95	485	22	258	300	114	309	148	9	580
Western	72	247	6	190	123	27	174	115	3	319
Total	317	946	34	701	528	154	586	424	99	1263

[a] Vendors with no formal education.
[b] Number of samples collected from each peanut market outlet.
[c] Values represent number of vendors falling in each category.

education or no formal education (Table 1). There was a significant ($P \leq 0.05$) association ($\chi^2 = 114.58$; $P < 0.001$) between education level and the gender of respondent (Fig. 4). The proportion of male respondents with no formal education was 2.5% compared to 15% for female respondents. The proportion of female vendors with primary and secondary education was 51% and 28%, respectively, compared to 32% and 50% for males. Only 8% of peanut traders had some form of tertiary education. A significantly ($P \leq 0.05$) higher proportion (24%) of traders in Nairobi had tertiary education compared to vendors elsewhere. In the Kenya National Youth Policy, a youth is defined as someone between the age of 18 and 35 years (http://www.marsgroupkenya.org/pdfs/2008/10/national_youth_policy.pdf, 2012). Over half (56%) of peanut traders were in this category. Forty two per cent of traders were over 35, while only 3% were under 18 years old. The maximum age of vendors recorded in Nairobi was 60 years compared to 73 and 80 years in Western and Nyanza provinces, respectively.

3.2. Relationship between type of peanut market outlet and education level of vendors

Peanuts in Kenya were commonly (44%) traded through informal open air markets[3] (Table 2). The least popular outlets for trading peanuts were formal open air markets[4] with only 4% of the peanuts sampled being traded there. There was a significant correlation ($\chi^2 = 559.60$; $P < 0.001$) between the level of education of traders and choice of type of market outlet. The majority of traders who had only basic or no formal education traded mainly through the informal open air markets, while those with tertiary education traded mainly through supermarkets and retail outlets (Table 2). For example, 83% of all street vendors had either basic or no formal education, while 98% of supermarket traders had either a secondary or tertiary education. Retail outlets were dominated (56%) by traders with secondary level of education.

The majority (61%) of peanuts and peanut products were bought locally, even though a sizeable amount (20%) was imported from neighboring countries mainly Uganda, Tanzania, Malawi and Zambia (Table 3). One fifth of all peanut samples in the market were from traders who were producing and directly marketing their own produce. Fifty five per cent of peanuts that were bought either locally or imported from neighboring countries were traded through middlemen while direct trading accounted for 45%. The proportion of respondents who did not know the source of their peanuts was less than 0.2%.

3.3. Description of peanut product types and packaging materials

The most common peanut products in the market were raw shelled kernels (53%) and roasted peanuts (22%), which were predominantly sold in Nairobi and western provinces, respectively (Table 4). Raw podded peanuts were only found in western Kenya, while peanut butter was commonly marketed in Nairobi and Nyanza provinces. Other products in the market included boiled peanuts, peanuts fried in oil, peanut flour as well as spoilt nuts.

Polyvinyl chloride (PVC) and propylene bags were the most common packaging materials for different peanut products (Table 4). However, preference for packaging material was dependent on the peanut product. Whereas shelled and podded raw nuts were commonly packaged in propylene bags, PVC was the preferred material for roasted and fried peanuts, while peanut butter was commonly packaged in plastic jars. There was negligible packaging of peanuts in jute bags.

3.4. Crop protection practices and storage structures

Peanut vendors used five crop protection measures aimed at maintaining quality and managing pests (Table 5). Sorting was the most common (58%) measure, while drying (20%) and sieving (16%) were also widely practiced. Almost a third of the vendors did not use any measures to maintain quality and avoid pests.

The floor of peanut storage structures in the three study regions was either made of mud (60%) or concrete (40%), while a negligible proportion was made from wooden material (Table 6). The majority of the stores were dusty with no windows for ventilation. Sixteen percent of the structures were infested with insects, with Nairobi being the worst affected. One out of eight stores was characterized by poor lighting and a musty smell.

3.5. Aflatoxin contamination levels of various peanut products

Raw podded peanuts had the lowest ($\chi^2 = 167.78$; $P < 0.001$) aflatoxin contamination, with 96% having levels of less than 4 μg/kg and only 4% having more than 10 μg/kg (Table 7). Independent of provenance, 69% of peanut butter products and 75% of spoilt nuts had aflatoxin levels exceeding 10 μg/kg. The majority of samples (59%) had aflatoxin contamination levels below 4 μg/kg (Table 7). Only 4% of the peanuts and peanut products would have been accepted under the KEBS regulation but rejected under the EU regulations. However, 37% of the peanuts would have been declared unfit for human consumption under the KEBS and EU regulatory limits (>10 μg/kg). A significantly ($\chi^2 = 264.76$; $P < 0.001$) higher number of samples traded in Nairobi exceeded the 10 μg/kg total aflatoxin limit according to KEBS regulations compared to samples traded in western Kenya. For example, 64% of the total number of samples collected from Nairobi (whether open air, stockists, retail or supermarkets) had more than 10 μg/kg aflatoxin. Similarly, while only 30% of the samples from Nairobi would have met the EU regulatory limit for aflatoxin (Fig. 5), 44% and 83% of products from

[3] Informal open air market: comprises of a temporary shed for selling peanut, with no permanent structure. A vendor could be at a different spot of the market in different days.
[4] Formal open air market: was defined as a peanut outlet comprising of a permanent structure for selling peanuts, mostly with a concrete, wooden or iron sheet wall, and a permanent roofing material made of concrete, iron sheet or timber. A trader would be found in the same place over a period of time.

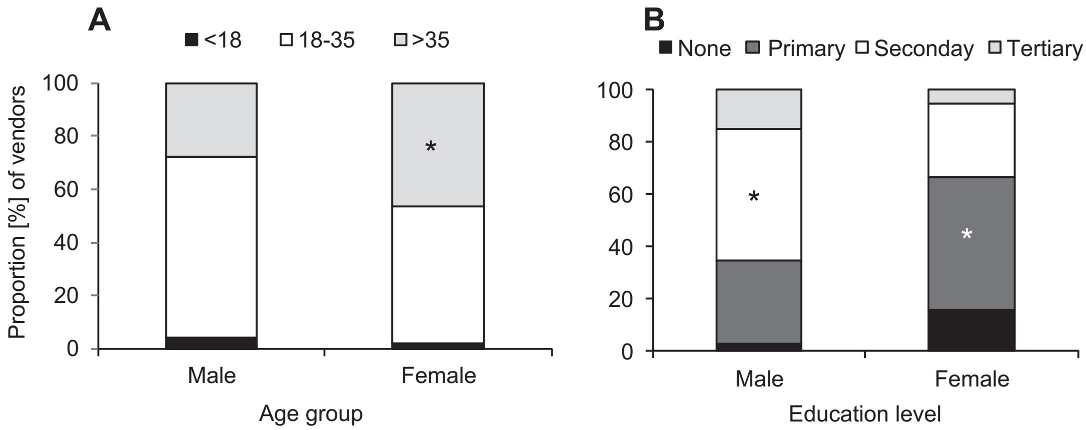

Fig. 4. Proportion [%] of peanut vendors in various categories based on gender: (A) Age group and (B) Education level. Asterisks indicate significantly ($p \leq 0.05$) different proportions between males and females either for age group or education level.

Western and Nyanza provinces respectively would have met the EU threshold. Only 50% of the peanut products indicated manufacture and expiry dates; 49% did not, while 1% had dates that were not legible.

3.6. Association between type of market outlet and aflatoxin contamination

There was a significant ($\chi^2 = 95.13$; $P < 0.001$) association between aflatoxin level and the type of peanut market outlet. Most peanuts from all market outlets had aflatoxin levels below 4 μg/kg (Table 8). High levels of contamination were observed in peanut products traded in retail markets with 44% of the samples exceeding 10 μg/kg (Table 8). Samples traded by hawkers and in informal open air markets had low aflatoxin contamination levels with 59% and 52%, respectively having less than 4 μg/kg aflatoxin content. Most (71.8%) of the peanut products from supermarkets had aflatoxin levels ≤4 μg/kg and only 26.5% had aflatoxin levels >10 μg/kg.

3.7. Association between type of packaging and aflatoxin contamination

There was a significant association ($\chi 2 = 73.89$; $P < 0.001$) between the packaging material of the peanut products and the levels of aflatoxin recovered from peanuts products. Although only 1% of the total samples were packaged in jute bags, all of them had aflatoxin levels below 4 μg/kg. High levels (>10 μg/kg) of aflatoxin contamination were found in the majority (68%) of the samples stored in plastic jars (Table 9). Over 35% of samples packed in propylene, metal tins and PVC bags had aflatoxin levels higher than 10 μg/kg (Table 9).

3.8. Implications of reducing Kenyan tolerance levels for aflatoxin in peanut products from 20 μg/kg to 10 μg/kg

The increase in the number of samples that would be rejected under the current and stricter KEBS standards of 10 μg/kg from 36% to 38% was not significant ($P \geq 0.05$). Furthermore, while 6% of all samples would be rejected under the EU standards, but accepted under the older KEBS standards, 4% would remain acceptable in this category under the newer and stricter KEBS standards (Fig. 6). However, at the national level, the revised KEBS standard will result in an estimated loss of tradable shelled peanuts amounting to 380 tonnes per year, based on the annual production for the country as provided by the FAO statistics for the year 2012.

4. Discussion

This study focused on understanding the marketing aspects of peanuts in Kenya, especially those attributes recognized as having a bearing on levels of aflatoxin in peanut products. The findings depict peanut trade as predominantly carried out within the informal sector, with a gender skew toward greater female participation. Most of the traders within this sector have minimal or no formal education, with more traders with formal education being in Nairobi compared to other areas. This is expected, considering that the capital city has a high turnover of youth with formal education and no employment, subsequently turning to trading

Table 2
Incidence [%] of traders in Nairobi, Western and Nyanza provinces in different education level categories and their choice of peanuts market outlets.

Type of market outlet	Non-formal	Primary	Secondary	Tertiary	Total [*n*][a]
Hawker	1.4 (18)	10.2 (129)	2.2 (28)	0.2 (2)	177
Informal open air market	7.8 (99)	24.9 (314)	10.9 (138)	0.3 (4)	555
Formal open air market	0.1 (1)	2.1 (26)	1.7 (21)	0.2 (3)	51
Stockist	2.1 (27)	4.5 (57)	5.2 (66)	1.1 (14)	164
Retail outlet	0.7 (9)	4.5 (57)	7.0 (88)	0.3 (4)	158
Supermarket	0 (0)	0.2 (3)	6.6 (83)	5.7 (72)	158
Total	12 (154)	46 (586)	34 (424)	7.8 (99)	1263

Numbers in parentheses represent *n* in every category.
[a] Number of samples collected from each peanut market outlet.

Table 3
Frequency [%] of mode of transaction of peanuts in various market outlets in Nairobi, Western and Nyanza provinces of Kenya ($N = 1263$).

Source of sample	Nairobi		Nyanza		Western	
	Direct	Middlemen	Direct	Middlemen	Direct	Middlemen
Own harvest	0.0	0.0	17.9	0.0	1.7	0.1
Bought locally[a]	2.6	18.9	11.3	13.5	6.6	8.2
Neighboring countries[b]	0.1	7.1	0.2	3.1	4.8	4.2
Does not know	0.0	0.2	0.0	0.0	0.0	0.0
Total [%]	2.7	26.2	29.4	16.6	13.1	12.5

[a] Peanuts from within Kenya including those sourced from processing companies.
[b] Peanuts imported from Malawi, Tanzania, Uganda and Zambia.

Table 4
Frequency [%] of use of packaging material for different peanut products marketed in Nairobi, Western and Nyanza provinces of Kenya.

Peanut product	Jute bags	Propylene bags	Metal tins	PVC bags	Paper	Plastic jars	Plastic basin	Reeded basket	Others[b]	Total [n][c]
Podded raw nuts	0.0[a]	58.7	0	6.3	0	1.6	19	14.3	0	63
Shelled raw peanuts	0.9	58.2	1	16.9	0.3	2.2	7.3	12.9	0.2	668
Roasted peanuts	0	0.7	3.2	64.3	13.6	2.9	10	3.9	1.4	280
Peanut butter	0	1.1	0	26.1	0	71.6	0	1.1	0	88
Boiled peanuts	0	16.7	0	22.2	0	5.6	5.6	50	0	18
Fried peanuts	0	0	0	100	0	0	0	0	0	32
Spoilt peanuts	0	65.5	3.4	13.8	0	3.4	13.8	0	0	29
Others[d]	0	7.1	0	67.1	0	10.6	12.9	2.4	0	85
Mean [%]	0.1	26	1	39.6	1.7	12.2	8.6	10.6	0.2	1263

[a] Values represent frequency of packaging material used for each product.
[b] Other packaging materials used include: metal basin, open metallic bowl and timber tray.
[c] Number of samples collected for each peanut product.
[d] Other peanut products include: Fried powdered nuts, milled nuts, nuts fried with masala, roasted cake, podded roasted nuts, roasted powdered peanuts, powdered nuts, peanut flour, roasted de-coated peanuts and soaked peanuts before roasting.

peanuts as a livelihood source. The Nairobi region also has more formal marketing outlets for peanut trading compared to the other regions and the study has shown that majority of traders within the formal market outlets have formal education.

Thirty seven percent of the samples taken from various markets exceeded the set threshold of aflatoxin levels by KEBS. A previous study by Mutegi et al. (2009) in western Kenya reported a possible increase in aflatoxin contamination of peanut products at market level as compared to household level, due to poor post-harvest handling. Studies in other countries have also reported high levels of aflatoxin contamination of peanuts and peanut by-products at market level (Bankole and Eseigbe, 2004; Le Anh, 2002; Ila et al., 2001; Verma and Agarwal, 2000). Storage time has also been previously discussed as a factor that would lead to increases in aflatoxin post-harvest (Hell et al., 2000). The previous study by Mutegi et al. (2009) also elucidates an increase in levels of aflatoxin over time in peanuts after harvest.

Peanuts purchased in outlets from Nairobi province were more contaminated than peanuts from Western and Nyanza provinces. Peanut products sold in Nairobi are rarely grown in the region, and are either transported from other regions locally or internationally. Furthermore, contamination of peanuts by aflatoxins can occur during production, storage, transportation and marketing (Hell and Mutegi, 2011; Nigam et al., 2009). In the case of Nairobi, the majority of peanuts are transported from other regions – whether within the country or from outside – by trucks (data not shown), and this could take one or several days, during which environmental factors such as rainfall, humidity, temperatures and respiration are likely to accelerate contamination by aflatoxin. Aflatoxin contamination has been shown to increase 10 fold in a 3-day period, when grains are stored with high moisture content (Hell et al., 2008). The findings in this study also indicated that many products traded in Nairobi come from other countries and are mainly traded through middlemen, both aspects which were linked to an increase in the likelihood of aflatoxin contamination. Aflatoxin contamination could be further aggravated by poor storage facilities, which was evident from the high proportions of peanuts recorded as infested with insects and stored in dusty, poorly ventilated premises.

Nuts stored in pods had the lowest levels of aflatoxin. The pods of nuts are likely to act as a protection against fungi that penetrate the kernels. Breaking of pods – through mechanical damage, by insects or during drought stress in the last stages of growth – increases chances of fungal contamination and subsequent aflatoxin contamination of the kernels (Dorner et al., 1989; Hell et al., 2000; Kaaya and Warren, 2005).

There were low aflatoxin contamination levels of raw peanut kernels with the majority of samples having less than 4 μg/kg aflatoxin content. Raw peanut kernels were mainly sold through the informal markets; subsequently, one would have expected such nuts to be high in aflatoxin levels compared to other peanut products. Their low contamination levels could be attributed to the fact that a major proportion is sold in shell, which acts as a protective shield against entry of aflatoxin-producing fungi. Secondly, raw peanut kernels are likely to have undergone sorting whereby discolored, broken or shriveled nuts are discarded, as willingness to purchase this category of product is influenced by the visual wholesomeness of the kernels.

On the other hand, contamination levels in peanut butter and spoilt nuts were high. Most of the peanut butter in Kenya is made by cottage scale manufacturers, from nuts that elude inspection mechanisms and are therefore likely to be contaminated. Considering that peanut butter is not a product constituting of whole kernels and that its final presentation does not exhibit physical aspects of deterioration of nuts, traders and processors are likely to take advantage of this and channel low grade peanuts for making peanut butter. Such nuts, which are cheaper than wholesome kernels, are characterized by discoloration, shriveling, and breakages, aspects that have been positively linked with aflatoxin contamination. Additionally, about half of the peanut butter products did not show expiry or manufacture dates making it difficult

Table 5
Incidence [%] of crop protection measures practiced by vendors in various market outlets in Nairobi, Western and Nyanza provinces of Kenya.

Region	Sieving	Sorting	Tumbling	Drying	No measure[a]	Winnowing	Total [n][b]
Nairobi	25.3	51.4	5.8	4.7	46.2	0.0	364
Nyanza	11.9	58.6	6.4	45.3	12.4	0.0	580
Western	11.0	64.3	6.0	11.0	32.6	0.9	319
Mean	16.1	58.1	6.1	20.0	30.4	0.3	

[a] No crop protection measures practiced by traders.
[b] Number of samples collected from each province.

Table 6
Characteristics of structures used for storage of peanuts by traders in various market outlets in Nairobi, Western and Nyanza provinces of Kenya [%].

Store characteristic	Nairobi	Nyanza	Western	Mean
Dusty	65.4	88.3	63.0	72.2
Infested by insects	26.1	15.2	5.3	15.5
Cracks in floor	33.8	66.2	13.2	37.7
Poor lighting	11.5	13.4	7.2	11.9
Poor ventilation[a]	58.0	78.3	87.8	74.7
Musty smell	20.9	9.1	4.7	11.6
Total [n][b]	364	580	319	

[a] Stores without windows; $N = 1263$.
[b] Sample size from the different provinces.

Table 7
Proportion (%) of peanut products in each aflatoxin level category sampled from various market outlets in Nairobi, Western and Nyanza provinces of Kenya.

Region	Peanut product	Proportion [%] in each aflatoxin limit category			Total [n]
		≤4 μg/kg[a]	>4–10 μg/kg	>10 μg/kg	
Nairobi	Shelled raw peanut	24.1	2.8	73.1	108
	Roasted peanuts	41.9	6.9	51.3	160
	Peanut butter	2.9	0.0	97.1	35
	Fried peanuts	40.7	14.8	44.4	27
	Spoilt peanut	0.0	9.1	90.9	11
	Others[b]	11.8	5.9	82.4	17
	Mean	20.3	6.6	73.2	358
Nyanza	Podded raw nuts	100.0	0.0	0.0	52
	Shelled raw peanut	82.3	2.9	14.8	385
	Roasted peanuts	75.3	6.2	18.5	81
	Peanut butter	52.8	8.3	38.9	36
	Boiled peanut	88.9	0.0	11.1	18
	Fried peanuts	87.5	0.0	12.5	8
	Spoilt peanut	44.4	0.0	55.6	9
	Others[b]	0.0	0.0	100.0	6
	Mean	64.4	2.2	31.4	595
Western	Podded raw nuts	50.0	0.0	50.0	4
	Shelled raw peanut	46.6	2.6	50.9	116
	Roasted peanuts	60.5	0.0	39.5	38
	Peanut butter	20.0	0.0	80.0	10
	Boiled peanut	100.0	0.0	0.0	1
	Fried peanuts	100.0	0.0	0.0	1
	Spoilt peanut	25.0	0.0	75.0	4
	Others[b]	10.3	0.0	89.7	29
	Mean	52.0	0.0	48.0	203

[a] Limit of detection = 2 μg/kg.
[b] Other peanut products include: Fried powdered nuts, milled nuts, nuts fried with masala, roasted cake, podded roasted nuts, roasted powdered peanuts, powdered nuts, peanut flour, roasted de-coated peanuts and soaked peanuts before roasting.

for the end consumer to forecast the quality of the product. High contamination levels in peanut butter have previously been reported from Sudan (Younis and Malik, 2003) and Nepal (Koirala et al., 2005).

Furthermore, to avert channeling of spoilt peanuts toward food uses, alternative uses of low grade peanuts should be explored. These include pressing the nuts for oil and ammoniation, which renders the peanuts unfit for human consumption, but fit for livestock feed. Depending on the level of aflatoxin, contaminated nuts can also be directly channeled into livestock feed manufacture. For example, based on the FDA standards, permissible limits for peanut and corn products for breeding cattle, finishing swine and finishing beef are 100 μg/kg, 200 μg/kg and 300 μg/kg respectively (Okongo, 2011).

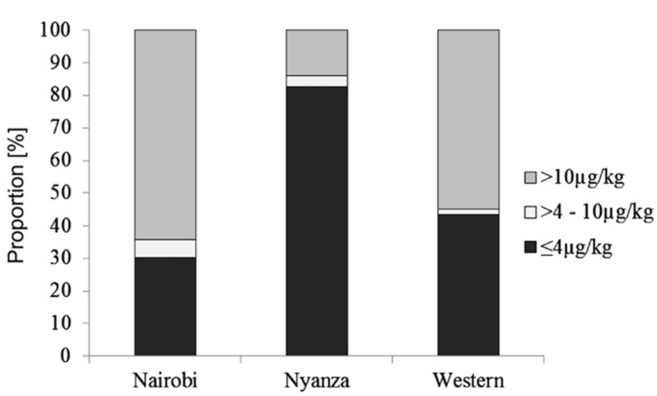

Fig. 5. Proportion [%] of marketed peanuts and peanut products within aflatoxin contamination levels of ≤4 μg/kg, >4 μg/kg - ≤10 μg/kg or >10 μg/kg from Nairobi, Nyanza and Western Provinces of Kenya.

Table 8
Relationship between aflatoxin level categories and market types for peanuts and peanut products from Nairobi, Nyanza and Western provinces of Kenya.

Market type	Incidence [%] of aflatoxin level category				Total [n][b]
	≤4 μg/kg	>4–10 μg/kg	>10 μg/kg	Max. [μg/g][a]	
Hawker	58.6	1.9	39.5	22,064	162
Informal market outlets	52.0	3.9	44.1	14,704	488
Formal market outlets	65.3	6.1	28.6	121	49
Stockist	65.1	5.4	29.5	32,328	149
Retailer	51.0	4.9	44.1	15,149	143
Supermarket	71.8	1.8	26.5	7581	170
Mean	60.6	4.0	35.4		1161

[a] The highest level of aflatoxin in parts per million detected in each market type.
[b] Number of samples collected from each peanut market outlet.

In the absence of adequate knowledge and awareness raising, the low cost that low grade or spoilt peanuts attract, makes them attractive to the majority of consumers with low purchasing power, but on the other hand increases the risk of chronic exposure to aflatoxin. Considering the low level of awareness as evidenced by such trading patterns, investment in education is necessary. Success of information campaigns has been evidenced elsewhere (James et al., 2007).

Most traders stored or packaged their peanuts in material other than sisal bags. The packaging material used was also found to influence aflatoxin levels in the stored peanuts. There is evidence that storage methods can facilitate fungal proliferation and aflatoxin contamination in maize (Hell et al., 2000; Udoh et al., 2000). In spite of this, informal marketing systems for peanuts in Kenya pose a challenge for regulation and establishment of proper systems for post-harvest handling, especially for small-scale traders.

Several cultural practices such as sorting, sieving, tumbling, winnowing and drying, that were used by the traders are recommended as ways of reducing aflatoxin contamination of peanuts. Sorting out physically damaged and infected grains from produce can result in 40–80% reduction in aflatoxin levels (Park, 2002). However, of concern is the fact that one third of all peanut traders used no such methods, in spite of their documented success in managing post-harvest aflatoxin contamination.

Although the decline in samples that would be deemed fit for human consumption after revising the KEBS tolerance levels for total aflatoxin was not significant, the resulting loss of 380 tons of

Table 9
Association between packaging material for peanuts and peanut products and levels of aflatoxin in the products sampled from Nairobi, Western and Nyanza provinces of Kenya.

Packaging type	Incidence [%] of aflatoxin level category				Total [n]
	≤4 μg/kg	>4–10 μg/kg	>10 μg/kg	Max. [μg/g][a]	
Jute bags	100.0	0.0	0.0	0.003	6
Propylene bags	60.9	2.9	36.2	15,149	409
Metal tins	55.6	0.0	44.4	36	18
PVC bags	55.7	3.6	40.7	32,328	393
Paper	43.9	14.6	41.5	147	41
Plastic jars	29.7	2.2	68.1	22,064	91
Plastic basin	69.5	3.2	27.4	3704	95
Reeded basket	73.1	4.8	22.1	58	104
Others[b]	50	25	25	0.05	4
Mean	59.8	6.3	33.9		1161

[a] The highest level of aflatoxin in parts per million detected for each packaging material.
[b] Other packaging materials used include: metal basin, open metallic bowl and timber tray.

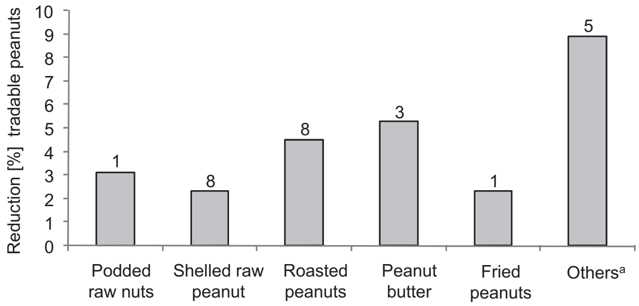

Fig. 6. Percentage reduction in tradable peanuts and peanut products in relation to revision of aflatoxin threshold levels from 20 μg/kg to 10 μg/kg by the Kenya Bureau of Standards. Values accompanying bar graphs represent the difference in number of samples per peanut product with aflatoxin contamination level >10 μg/kg but ≤20 μg/kg.

tradable shelled peanuts per year in the country would still directly impact on income and livelihoods of peanut traders. Thus, unless strict monitoring measures are put in place to ensure that the regulatory standards for aflatoxin are upheld, condemned nuts will continue to be available in the markets for human consumption. High aflatoxin contamination at market level implies that the prevailing post-harvest handling practices are insufficient in controlling contamination and in some cases, have worsened contamination levels. Ultimately, the choice of lowering regulatory limits ought to be considered against the health implications of the current standards. Secondly, regulatory standards need to be coupled with strict monitoring systems to ensure they are upheld. Thirdly, there needs to be a premium price for good quality kernels in order for traders to invest in clean products. To achieve this, there is need for awareness creation at all levels of the peanut value chain, especially for end consumers, in order to enhance the understanding of the benefits of purchasing/consuming low risk products. Sorting (Whitaker et al., 2005; Williams et al., 2004) and use of other low cost technologies have been shown to substantially reduce aflatoxin levels in peanuts (Turner et al., 2005) and hence such approaches, coupled with alternative use of contaminated nuts should be recommended together with regulatory approaches in the education campaigns.

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