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Mycotoxin and metallic element concentrations in peanut products sold in Ugandan markets

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Abstract: The increasing prevalence of cancer among Ugandans has aroused consumer concerns about food-borne carcinogens. This study sought to compare mycotoxin and metallic element concentrations in processed peanuts sold in selected markets in Kampala, Uganda to those traditionally prepared in homes. Market-processed peanut samples (n = 33) were purchased from four markets. Control samples (n = 5) were unground peanuts bought from markets but processed in homes by traditional methods. Aflatoxins B1, B2, G1, G2; Fumonisins; Deoxynivalenol, Nivalenol, Ochratoxin A, T2 toxin, Zearalenone, and Zearalenol were analyzed by LC/MS/MS while As, B, Ba, Cd, Cr, Cu, Hg, Mg, Ni, Pb and Zn were analyzed by ICP/MS. The data was statistically analyzed using Wilcoxon scores (rank sums) or the Kruskal-Wallis test. Aflatoxins were the predominant mycotoxins found in significant amounts. 55 and 34% of the samples had concentrations of total aflatoxins greater than 20 ppb (FDA acceptable limit). There were significantly higher concentrations of aflatoxins in market-processed than in home-processed samples. Metallic element concentrations were generally below FDA maximum acceptable concentrations. Roasting and duration of grinding had no significant effect on aflatoxin or metallic element concentrations. There is a need for food-borne toxicant monitoring of food sold in public markets in Uganda.

Wilson Kiiza Rumbeiha

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PUBLIC INTEREST STATEMENT

Human diseases have a number of causes including exposure to toxins. One of the sources of toxins is food, which can become contaminated at any stage from farm to table. In Uganda there is a major concern about the high prevalence of cancer and food-born toxins are suspect. This study has shown that peanut products sold in Kampala markets have violative aflatoxin residues by EU and the US Food and Drug Administration standards. However, careful selection of quality peanuts and processing them traditionally at home is a safer practice than purchase of products whose background and quality is unknown. Food consumers need to be vigilant in order to protect their health by buying food products free of toxins. We recommend that regulatory authorities step up to protect consumers by ensuring that only safe food is sold in public markets. When this is achieved, human health will be improved.

Subjects: Food Science & Technology; Cancer; Environmental health

Keywords: food contaminants; food toxicology; food science; food safety; metallic element contaminants; mycotoxins

1. Introduction

Food contaminants can negatively impact health of consumers. In Uganda, there is minimal oversight of the quality of food and food products sold in markets. Because of the high prevalence of cancer among the Ugandan population, there are consumer concerns about food as source of carcinogens, contributing to the burden of cancer and other illnesses in the country. There is open public discussion about potential contamination of market foods by mycotoxins and metallic elements. Whereas moldy food is the likely source of mycotoxins, the wear and tear of poorly fabricated metallic food processing equipment is suspected to be a source of contamination of processed foods with metallic elements. In most cases, food is processed in cottages within markets without proper oversight.

Peanuts (*Arachis hypogaea* L.) are widely used in many Ugandan diets or dishes; roasted to a greater or lesser extent, and prepared in many forms as whole grain or processed into flour or peanut butter (Kaaya, Harris, & Eigel, 2006). Peanuts are an excellent source of amino acids, especially for the poor who cannot afford animal proteins on a regular basis. The multiple uses of peanuts make them an excellent staple food and cash crop for local and international trade (Okello, Biruma, & Deom, 2010). However, fungal and mycotoxin contamination is a major challenge facing the peanut industry. High temperature and humidity are key predisposing factors to fungal growth on peanuts (Darwish, Ikenaka, Nakayama, & Ishizuka, 2014). Peanuts are among the most susceptible crops to fungal contamination and the Ugandan consumers are exposed to far higher levels of aflatoxins than the FDA's acceptable level of 20 ppb (Kaaya et al., 2006; Nyirahakizimana et al., 2013). Typically, traders purchase peanuts during the harvest season and store them in bulk under poor sanitary conditions, which promote mold growth and production of mycotoxins such as aflatoxins, fumonisins, ochratoxins, trichothecenes and zearalenone. Other studies have demonstrated presence of mycotoxins in various foods in Uganda (Kitya, Bbosa, & Mulogo, 2010). However, the tests were limited to aflatoxins, and no comprehensive study has ever been undertaken to study potential contamination by other mycotoxins and metallic elements at the same time. Also, this is the first study to compare contaminants in market and home processed peanut food products.

This study was carried out to determine the concentrations of several mycotoxins and metallic elements in processed peanut products sold in selected markets in Kampala, Uganda. The main objective was to compare contaminants of the processed peanuts sold in markets and peanuts traditionally prepared in homes. However the effect of roasting and duration of grinding was also evaluated. The hypothesis of this study was: "peanuts sold in Ugandan markets contain higher concentrations of toxic metallic elements and mycotoxins than traditionally home prepared peanuts".

2. Materials and methods

2.1. Sample collection

Thirty-three market-processed peanut samples were purchased from St. Balikuddembe (also called Owino), Nakawa, Kalerwe, and Bukoto markets in the Kampala metropolitan area in Uganda (Figure 1). Sixteen of these samples were processed from unroasted peanuts; 11 from roasted peanuts while for the rest of the samples the preparation of peanuts prior to processing was unknown (Table 1). The duration of the grinding of the processed peanuts was recorded (Table 1). Control samples (n = 5, 500 g each) were unground peanuts bought from the same markets and taken to two homes in Kampala for processing by traditional to metal manual pounding. Additionally commercial peanut butter samples (n = 5) were obtained from supermarkets in Ames, IA USA and later analyzed as a reference.

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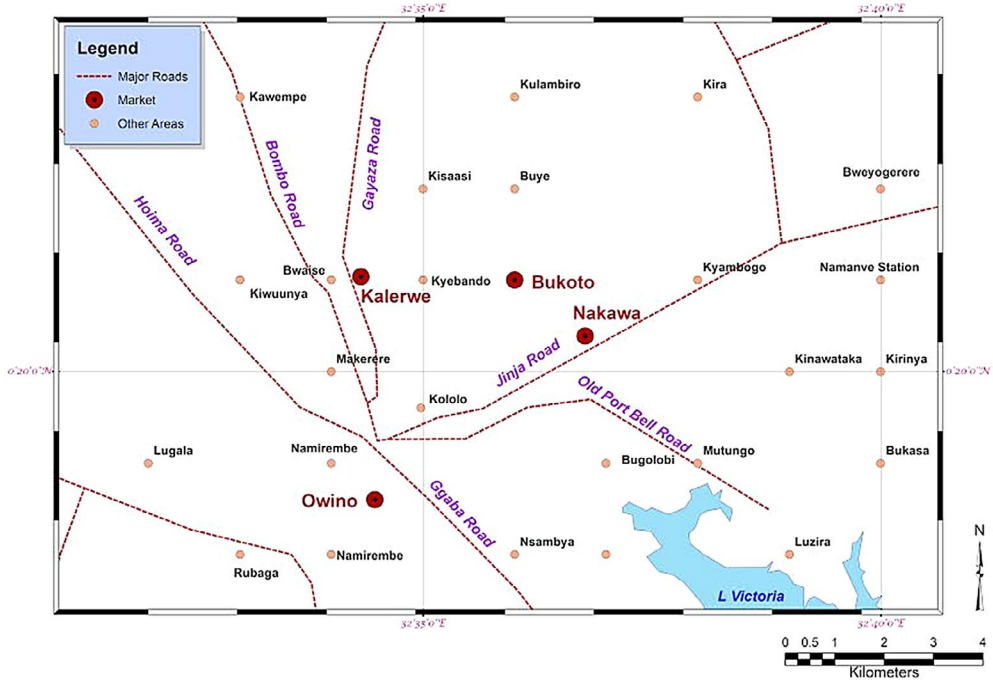

Figure 1. Map of Kampala showing markets where peanut samples were purchased.

Note: Reproduced with permission from Kampala Capital City Authority.

The samples were placed in plastic containers, sealed immediately and labeled using a marker with a code according to the market and stall from which it was picked e.g. K101 bought from Kalerwe stall 1, sample number 1; or N101 bought from Nakawa stall 1, sample number 1. The labelled samples were placed in an icebox and transported to the Food Safety Laboratory at the College of Veterinary Medicine, Animal Resources and Biosecurity (COVAB) of Makerere University where they were stored at −20°C for 5 days before they were shipped to the USA for analysis at the Veterinary Diagnostic Laboratory, College of Veterinary Medicine, Iowa State University.

2.2. Laboratory analysis for mycotoxins

Samples were analyzed for the following mycotoxins: Aflatoxin B1, B2, G1, G2; Fumonisin B1, B2, B3; Deoxynivalenol, Nivalenol, Ochratoxin A, T2 toxin, Zearalenone, and Zearalenol following standard operating procedures (SOP) for mycotoxin analysis at the Iowa State University Veterinary Diagnostic laboratory, Ames, IA. This laboratory is accredited by the American Association of Veterinary Laboratory Diagnosticians. Briefly, following thawing at room temperature, peanut samples were analyzed on a wet weight basis. 5.0 g Samples were weighed into a 50 mL glass tubes and 25 mL of extraction solvent (methanol/water; 80/20 *v*/*v*) was added. The tubes were placed on a roto-rack for 30 min followed by centrifugation at 2,000 rpm for 5 min. The extracts were then diluted 1:3 with a solution containing 5 mM ammonium acetate with 1% acetic acid in 10% methanol. After dilution 50 µL was injected into the LC/MS/MS system. For quality control, a negative control (a mycotoxin free feed), a positive control (the negative control feed fortified with the aflatoxins at a concentration of 20 ppb and 1 ppm for the other mycotoxins), and a certified reference corn sample (Trilogy Analytical Laboratory) were analyzed with each batch of peanut samples.

The mycotoxins were identified and quantified using a Varian 310 triple quadrupole LC/MS/MS equipped with a Varian ProStar Model 410 autosampler and two Varian ProStar pumps (Agilent Technologies, Santa Clara, CA). Mobile phase A was 5 mM ammonium acetate with 1% acetic acid in 10% methanol while mobile phase B was 5 mM ammonium acetate with 1% acetic acid in 100% methanol. Mobile phases A and B were run as a gradient to allow for baseline separation of all the mycotoxins in the panel. The limit of detection for aflatoxins was 0.8 ppb and the limit of

Table 1. Categories of the collected peanut samples by market

Sampling site	Number of samples				
A: State prior to processing	*Unroasted*	*Roasted*	*Unknown*	*Total*	
Bukoto market	2	1	1	4	
Nakawa market	4	1	4	9	
Kalerwe market	5	3	2	10	
Owino market	2	3	5	10	
Home processed samples	3	2	0	5	
Total	16	10	12	38	
B: Duration of the grinding	*<10 min*	*10–30 min*	*>30 min*	*Unknown*	*Total*
Bukoto market	0	1	2	1	4
Nakawa market	3	1	4	1	9
Kalerwe market	3	1	4	2	10
Owino market	4	0	2	4	10
Total	10	3	12	8	33*

*Total does not include the five samples traditionally-processed in the homes.

quantification was 5 ppb and for the other mycotoxins was 40 ppb and 0.1 ppm respectively (Imerman, 2010; Rudrabhatla, George, & Faye, 2007).

2.3. Laboratory analysis for metals

Samples were analyzed for As, B, Ba, Cd, Cr, Cu, Hg, Mg, Ni, Pb and Zn using Inductively coupled plasma mass spectrometry (ICP-MS, Analytik Jena Inc. Woburn, MA, USA) in CRI mode with hydrogen as the skimmer gas (FSIS, 2013; Jarzyńska & Falandysz, 2011). Standards for elemental analyses were obtained from Inorganic Ventures (Christiansburg, VA) while digestion vessels, trace mineral grade nitric acid and hydrochloric acid were obtained from Fisher Scientific (Pittsburgh, PA). Following thawing at room temperature, peanut samples were processed and analyzed following the established SOP on a wet weight basis. Briefly, samples were digested in 70% nitric acid at 60°C for ≥12 h. 0.5 g samples were weighed into a 50 mL centrifuge tubes and 5 mL of 70% nitric acid was added. All samples were digested overnight at 60°C. After digestion, all samples were diluted to 25 mL using 1% nitric acid with 0.5% hydrochloric acid. An additional 1:10 dilution using 1% nitric acid with 0.5% hydrochloric acid was made and then analyzed by ICP-MS. For quality control, Bi, Sc, In, Li, Y, and Tb were used as internal standards for the ICP-MS.

2.4. Statistical analysis

Metallic element and mycotoxin concentrations in market-processed peanuts were compared with those in peanuts traditionally processed in homes using SAS (SAS Institute Inc., 100 SAS Campus Drive, Cary, NC 27513-2414, USA). Differences in concentrations between market samples were also statistically evaluated as well as the effect of duration of grinding and state of the peanuts before processing (roasted or unroasted) on analyte concentrations. All data was statistically analyzed using Wilcoxon scores (rank sums) or the Kruskal-Wallis test (for differences between markets) since the values of the variables were not normally distributed. All differences were considered statistically significant at $p < 0.05$.

3. Results

3.1. Mycotoxins

Of the different mycotoxins analyzed, aflatoxins were the predominant mycotoxins found in significant amounts in peanut samples. Deoxynivalenol, nivalenol, ochratoxins, T2 toxin, zearalenone and zearalenol were not present in any of the samples. The only other mycotoxins found were fumonisins. Fumonisin B1 and B2 were found in only 8% of the Ugandan samples (concentration range 0.2–0.6 ppb). On the other hand, aflatoxins were present in 82% of all Ugandan samples; with 55%

Table 2. Percent of samples in which aflatoxins were present

Percent of samples					
Concentration of aflatoxin	**AF-B1**	**AF-B2**	**AF-G1**	**AF-G2**	**Total aflatoxin**
>0 ppb	63%	45%	61%	68%	82%
≥12 ppb (EU limit)	47%	29%	47%	32%	66%
≥20 ppb (US FDA limit)	34%	16%	32%	8%	55%
ppb					
Concentration range	0–540	0–141	0–213	0–36	0–849

of the samples having concentrations greater than 20 ppb (Table 2). Aflatoxin concentrations were in the range of 0–540 ppb for aflatoxin B1, 0–141 ppb for aflatoxin B2, 0–213 ppb for aflatoxin G1, 0–36 ppb for aflatoxin G2 and 0–849 ppb for total aflatoxin. Aflatoxin B1 was most abundant aflatoxin in concentrations greater than 20 ppb (34% of the samples) as shown in Table 2.

There were significantly higher concentrations of aflatoxins B1, B2, G1, G2 and total aflatoxins in market processed samples than in home processed samples (Table 3). Roasting of the peanuts and duration of grinding had no statistically significant effects on concentrations of any aflatoxins in the peanuts (Tables 4 and 5). Similarly the source market of the peanuts also had no significant effect on aflatoxin concentrations (Table 6). In Ugandan samples, the highest concentrations of aflatoxin were B1 followed by G1 (Table 6). No aflatoxins were detected in samples purchased from supermarkets in USA.

Table 3. Mean aflatoxin concentrations in market and home processed samples

Aflatoxin	**Mean concentration (ppb) ± SEM**		***p* value**
	Market (*n* = 33)	**Home (*n* = 5)**	
Aflatoxin B1	103.1 ± 36.6	0.0 ± 0.00	0.0121*
Aflatoxin B2	25.1 ± 8.7	0.0 ± 0.00	0.0539
Aflatoxin G1	41 ± 12.5	0.0 ± 0.00	0.0153*
Aflatoxin G2	11.4 ± 2.39	0.0 ± 0.00	0.0071*
Total aflatoxin	180.7 ± 51	0.0 ± 0.00	0.0019*

*Significantly different at $p < 0.05$; Wilcoxon Rank Sum test.

Table 4. Effect of roasting on mean aflatoxin concentrations

Aflatoxin	**Mean concentration (ppb) ± SEM**		***p* value**
	Roasted (*n* = 10)	**Non-roasted (*n* = 16)**	
Aflatoxin B1	141.9 ± 72.34	46.7 ± 18.14	0.5768
Aflatoxin B2	34.5 ± 16.72	11.4 ± 4.96	0.3679
Aflatoxin G1	32.4 ± 16.58	33.6 ± 14.09	1.0000
Aflatoxin G2	7.8 ± 3.01	10.1 ± 2.95	0.6690
Total aflatoxin	216.6 ± 99.05	101.8 ± 32.93	0.5132

Table 5. Effect of duration of grinding on mean aflatoxin concentrations

Aflatoxin	**Mean concentration (ppb) ± SEM**		***p* value**
	<10 min (*n* = 12)	**>30 min (*n* = 10)**	
Aflatoxin B1	3.9 ± 2.238	36 ± 17.84	0.0783
Aflatoxin B2	1.5 ± 1.204	9 ± 5.17	0.1225
Aflatoxin G1	9 ± 5.675	22 ± 10.24	0.2136
Aflatoxin G2	5.4 ± 1.778	9.5 ± 2.759	0.2289
Total aflatoxin	19.8 ± 7.864	76.5 ± 29.35	0.1004

Table 6. Mean aflatoxin concentrations in peanuts from different markets

Aflatoxin	Mean concentration (ppb) ± SEM				*p* value
	Kalerwe (*n* = 10)	Bukoto (*n* = 4)	Nakawa (*n* = 9)	Owino (*n* = 10)	
Aflatoxin B1	60.3 ± 27.99	40.5 ± 12.82	10.3 ± 3.54	143.1 ± 72.16	0.4865
Aflatoxin B2	19.2 ± 7.12	4.5 ± 1.94	1.3 ± 0.88	32.7 ± 17.04	0.1182
Aflatoxin G1	40.5 ± 22.63	48.8 ± 12.39	23.7 ± 12.22	26.4 ± 13.14	0.2320
Aflatoxin G2	15.6 ± 3.89	8.3 ± 1.44	5.3 ± 1.92	6.3 ± 2.88	0.0679
Total aflatoxin	135.6 ± 49.39	102 ± 26.35	40.7 ± 17.26	208.5 ± 99.5	0.5307

Note: Analyzed using Kruskal-Wallis test.

3.2. Metallic elements

The concentrations of cadmium and lead in all 38 samples were below the detection limit (0.25 ppm). Only one Ugandan sample (2.6%) had arsenic concentration above the FDA maximum permitted concentration of 1.4 ppm (Choi, 2011). The concentrations of chromium and mercury in 100% of the samples were below the FDA acceptable limit of 1 and 0.5 ppm respectively.

Neither roasting nor duration of grinding had a statistically significant effect on metallic element concentrations in peanuts (Tables 7–9). There were significantly higher concentrations of barium in market-processed samples than in home processed peanut samples (Table 7). Paradoxically, the concentrations of zinc, nickel, magnesium and copper were significantly higher in home-processed

Table 7. Mean metallic element concentrations in market and home processed samples

Element	Mean concentration (ppb) ± SEM		*p* value
	Market (*n* = 33)	Home (*n* = 5)	
Chromium	0.3 ± 0.01	0.5 ± 0.02	0.0009*
Zinc	17.1 ± 0.67	21.2 ± 0.62	0.0253*
Boron	9.5 ± 0.23	9.0 ± 0.51	0.2343
Nickel	2.8 ± 0.22	3.9 ± 0.32	0.0374*
Barium	5.3 ± 0.25	3.4 ± 0.12	0.0051*
Magnesium	1,060 ± 27.46	1,222 ± 42.62	0.0340*
Mercury	0.05 ± 0.01	0.02 ± 0.00	0.1108
Copper	5.0 ± 0.17	6.1 ± 0.21	0.0151*
Arsenic	0.5 ± 0.06	0.6 ± 0.20	0.7285

*Significantly different at $p < 0.05$; Wilcoxon Rank Sum test.

Table 8. Effect of roasting on mean metallic element concentrations in peanuts

Element	Mean concentration (ppb) ± SEM		*p* value
	Roasted (*n* = 10)	Non-roasted (n = 16)	
Chromium	0.4 ± 0.04	0.3 ± 0.02	0.3427
Zinc	18.1 ± 1.14	16.9 ± 0.82	0.3928
Boron	9.4 ± 0.47	9.5 ± 0.31	0.7348
Nickel	3.3 ± 0.52	2.9 ± 0.28	0.3928
Barium	4.4 ± 0.45	5.1 ± 0.37	0.5849
Magnesium	1,090 ± 54.5	1,070 ± 37.32	0.5849
Mercury	0.06 ± 0.02	0.04 ± 0.01	0.9525
Copper	5.0 ± 0.40	5.05 ± 0.21	0.6960
Arsenic	0.5 ± 0.10	0.4 ± 0.05	0.6159

Table 9. Effect of grinding duration on mean metallic element concentrations in peanuts

Element	Mean concentration (ppb) ± SEM		*p* value
	<10 min (*n* = 10)	>30 min (*n* = 12)	
Chromium	0.3 ± 0.02	0.26 ± 0.01	0.1609
Zinc	17.1 ± 1.00	15.6 ± 0.76	0.1710
Boron	9.6 ± 0.27	9.3 ± 0.39	0.6261
Nickel	2.3 ± 0.26	2.5 ± 0.34	1.000
Barium	5.8 ± 0.50	5.5 ± 0.25	0.8197
Magnesium	1,094 ± 45.97	1,012 ± 45.24	0.3184
Mercury	0.04 ± 0.01	0.05 ± 0.01	0.5471
Copper	5.2 ± 0.24	4.7 ± 0.23	0.1710
Arsenic	0.6 ± 0.09	0.4 ± 0.07	0.1156

Table 10. Mean metallic element concentrations in peanuts from different markets

Element	Mean concentration (ppb) ± SEM				*p* value
	Kalerwe (*n* = 10)	Bukoto (*n* = 4)	Nakawa (*n* = 9)	Owino (*n* = 10)	
Chromium	0.24 ± 0.00	0.24 ± 0.00	0.3 ± 0.02	0.36 ± 0.03	<0.0001*
Zinc	15.3 ± 0.55	15.4 ± 1.46	19.1 ± 1.18	17.7 ± 1.61	0.1991
Boron	9.8 ± 0.33	9.4 ± 1.03	9.4 ± 0.46	9.4 ± 0.41	0.0851
Nickel	2.2 ± 0.36	3.1 ± 0.27	3.1 ± 0.41	3.0 ± 0.51	0.4874
Barium	5.8 ± 0.48	5.0 ± 0.45	4.9 ± 0.29	5.4 ± 0.63	0.5433
Magnesium	1,032 ± 34.31	997 ± 93.71	1,138 ± 59.58	1,041 ± 52.53	0.3879
Mercury	0.1 ± 0.01	0.04 ± 0.007	0.02 ± 0.00	0.02 ± 0.00	<0.0001*
Copper	4.6 ± 0.15	4.5 ± 0.50	5.4 ± 0.38	5.2 ± 0.35	0.2365
Arsenic	0.5 ± 0.04	0.9 ± 0.29	0.9 ± 0.10	0.4 ± 0.09	0.3380

*Significantly different, Kruskal-Wallis test.

samples than in market-processed samples as shown in Table 7. The concentrations of chromium and mercury in the peanut samples from the source markets were significantly different with Owino market samples having the highest concentrations of chromium while Kalerwe market samples had the highest levels of mercury (Table 10).

4. Discussion

The increasing prevalence of cancer in the Ugandan population has raised concerns about food as a potential source of carcinogens, including mycotoxins and toxic elements. Results of this study confirm earlier observations that aflatoxins are prevalent in Ugandan peanut products, and that B1 is the most predominant aflatoxin (Kaaya et al., 2006). Aflatoxins are carcinogens. The percentage of Ugandan peanut samples with aflatoxin concentrations above the US FDA and EU acceptable regulatory limits (66 and 55% respectively) are unacceptably high. These results are however comparable to aflatoxin concentrations in peanuts reported for other countries in the region. For example, in Kenya, Mutegi et al. (2013) showed that 69% of peanuts butter samples sourced from markets in the Central and Western provinces of the country had aflatoxin concentrations above the maximum acceptable limit set by the Kenya Bureau of Standards (10 ppb); indicating that aflatoxins pose a regional health problem. Similarly, studies in Iran found high percentage of peanut samples (48.4%) with aflatoxin concentrations above the national maximum acceptable limit of 15 ppb (Ostadrahimi et al., 2014). The causes of the high aflatoxin concentrations in our study could partly be attributable to poor hygiene in the production chain that includes harvesting, drying, processing and storage. In Kampala, business people buy peanuts in bulk during the harvest season when prices of

commodities are low and store them in poorly ventilated, highly humid premises. They process the peanuts and sell them in retail outlets, including markets. This could explain why market processed samples had significantly higher aflatoxin concentrations than home processed samples. The poor hygienic conditions of the processing equipment and premises in these poorly constructed, disorganized markets could result in mycotoxin carry over and cross contamination. Although home processed peanuts were purchased from the same markets, we were careful to select good quality grains for home processing. Yet consumers buy products which are already processed and marketed as flour or paste. It is hard to tell the quality of peanuts used in processing these products. There is no regulatory oversight to ensure that only mycotoxin free peanuts are processed for the market in Uganda. By contrast, there were no detectable aflatoxins in the control peanut butter samples from the United States where food safety standards are strictly enforced.

The duration of processing (grinding) and the roasting of the groundnuts did not have a statistically significant effect on aflatoxin concentrations. While heat has been shown to decrease contamination of foods by mycotoxins (Yazdanpanah, Mohammadi, Abouhossain, & Cheraghali, 2005), the effect depends on the heating temperature, heating time and initial concentration of the aflatoxins prior to heating (Arzandeh & Jinap, 2011). A study in Nigeria showed that peanuts roasted at 140°C for 40 min had 58.8 and 64.5% reductions in aflatoxins B1 and G1 respectively while roasting at 150°C for 25 min resulted in 68.5 and 73.3% reductions in aflatoxins B1 and G1, respectively (Ogunsanwo, Faboya, Idowu, Lawal, & Bankole, 2004). On the other hand, roasting at 150°C for 30 min resulted in 70.0 and 79.8% reductions in concentrations of aflatoxins B1 and G1 respectively. Similarly Diedhiou, Ba, Kane, and Mbaye (2012) showed a 64% decrease in aflatoxin content after roasting at 140°C for 60 min while results by Siwela, Mukaroa, and Nziramasanga (2011) indicated a 11% decrease in aflatoxin concentration after grinding to make peanut butter. In our study, the duration and temperature of roasting were not known and probably were not uniform; which could explain why no decrease in aflatoxin content was observed for peanuts roasted prior to processing. It is also possible that long-term storage in unhygienic conditions at room temperature following the roasting may nullify this effect because of mold re-infestation. The fact that there were no significant differences in aflatoxin concentrations between markets indicates that storage and handling conditions in the sampled markets are probably similar.

Results of metallic element concentrations were interesting, considering the frequent use of local poorly fabricated food processors. We had anticipated significant contamination by mineral elements from the wear and tear of such equipment. However, results were quite the opposite, with toxic elements of concern being non detectable and toxicologically inconsequential, which was reassuring. Overall, the concentrations of metallic elements were within Codex Alimentarius Commission (CAC) acceptable regulatory limits. The cadmium and lead concentrations were lower than the ICP/MS detection limit. Contrasting results have been obtained for Cd and Pb concentrations in peanuts in other countries. Cd concentrations in peanut products sampled from local markets and commercial producers in Brisbane were in the range of 0.013–0.031 ppm (Tinggi, 1998), well below the FDA maximum acceptable concentration of 0.1 ppm. However, mean Cd concentration in peanut samples in China over the period 2009–2014 was 0.1684 ppm (Xianhong et al., 2016), slightly above the regulatory limit. The mean lead concentration in peanuts in south-eastern Nigeria was 0.23 ppm (Orisakwe, Nduka, Amadi, Dike, & Bede, 2012), below the 6 ppm permitted in solid foods (Choi, 2011). Earlier studies in northeastern China (Zhang, Watanabe, Shimbo, Higashikawa, & Ikeda, 1998) showed lower mean Pb concentrations in other food crops such as rice (0.031 ppm), kidney beans (0.0308 ppm) and soybeans (0.0257 ppm). Concentrations of zinc, nickel, magnesium and copper were significantly higher in home-processed than market processed samples. No explanation is known at this time for this surprising finding. We had anticipated to find higher metallic element concentration in market processed samples than in home processed samples. One possible explanation could be wear and tear of metallic mortar and pestle routinely used in homes. More research needs to be done to confirm these results and establish the source of these elements. Nickel is carcinogenic and chronic copper ingestion causes liver injury (Wilson's disease).

We observed significant differences in Cr and Hg concentrations between markets. Potential local contamination with locales of the markets, like local industrial activities cannot be ruled out as a source of these differences. The markets are at least 10 km apart.

5. Conclusions and recommendations

Of the two classes of contaminants tested in peanut products on the Ugandan market, aflatoxins were most prevalent and posed greater concern. The percentage of sampled peanut products with concentrations exceeding the EU and US regulatory limits for aflatoxins was at least 55%. Aflatoxins are known carcinogens and hepatotoxic agents. These results support prevailing concerns by the general public in Uganda about food as a source of carcinogens and other toxicants targeting other organs. The traditional metallic mortar and pestle should further be investigated as a potential source metallic element concentration in food. These results call for a need for a strict regulatory oversight to protect consumers from food-borne contaminants in peanuts.

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Cover image
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