



ORIGINAL RESEARCH

Natural occurrence of aflatoxins and ochratoxin A in raw and roasted groundnut from Niger State, Nigeria

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ABSTRACT

Aflatoxins (AFs) and ochratoxin A (OTA) contamination of raw and roasted groundnut from Niger State, Nigeria was assessed. Eighty-one samples were randomly collected during the rainy season (May–October) from different locations in four microclimatic zones of Niger State and analyzed for aflatoxin B₁ (AFB₁), AFB₂ and OTA using high performance liquid chromatography. The three mycotoxins (AFB₁, AFB₂ and OTA) were found in 88.9, 75.3 and 90.1% of the samples respectively and the concentrations ranged 4.0–188 µg/kg for AFB₁, 0.4–38.4 µg/kg for AFB₂ and 0.8–45.6 µg/kg for OTA. All aflatoxin positive groundnut samples contained levels above the Nigerian and European Union (2 µg/kg) action limits for AFB₁ while 55% of the samples had OTA concentrations exceeding the 5 µg/kg regulatory limit of Nigeria and EU. Since groundnut is a staple food in Nigeria, consumption of contaminated kernels may contribute to an increased dietary exposure to AF and OTA in the studied population with possible health risks associated with such exposures.

Keywords: Aflatoxins, Groundnuts, Ochratoxin A

1.0 Introduction

Aflatoxins (AFs) are poisonous secondary metabolites produced mainly by *Aspergillus flavus*, *A. parasiticus* and *A. nomius*. The four major AFs: aflatoxin B₁ (AFB₁), AFB₂, AFG₁ and AFG₂; are the most agriculturally important mycotoxins in food and feed because of their abundant presence in nature and high toxicity (Makun et al., 2012). Aflatoxins especially AFB₁ are powerful human carcinogens that also elicit mutagenic and teratogenic effects (Raisuddin et al., 1993). These toxins play causative roles in the development of hepatocellular carcinoma (Liu and Wu, 2010) and have been the cause of deaths among humans in Eastern Province of Kenya (Azziz-Baumgartner et al., 2006; Probst et al., 2007), India (Krishnamachari et al., 1975) and Malaysia (Lye et al., 1995). On the other hand, ochratoxin A (OTA) elicits kidney and liver impairment in animals, especially in pigs (Battacone et al., 2010), and man (Reddy and Bhoola, 2010). It is also associated with Bulgarian porcine and chicken nephropathy (Stoev et al., 2009) as well as human kidney disorder commonly referred to as Balkan

Endemic Nephropathy (BEN) (Peraica et al. 1999). Aflatoxins and OTA are known to contaminate nuts and oilseeds, cereals, roots and tubers, fruits, vegetables and animal feed (Makun et al., 2012) particularly in warm, humid regions of the world. In fact groundnut is one of the most susceptible crops to aflatoxins (Makun et al., 2012).

Groundnut (*Arachis hypogaea* L.) is one of the major sources of protein for many West African countries. Apart from its use as food or snacks and oil, groundnut is also an important source of cash and a component of compound feed in Nigeria. It generates about 60, 42 and 21% of rural cash earnings for groundnut producers in Senegal, Niger and Nigeria, respectively and accounts for about 70% of rural employment in Senegal (Ntare, et al. 2005). During the last four decades, West Africa lost its position in world groundnut production and export shares as its production share declined from 23 to 15% whereas export share declined from 55 to 20% (ITC, 2001). Senegal and Nigeria are among the world's largest groundnut producers (Ntare et al.,

2005). Groundnut is produced mainly in Northern and Middle-belt regions of Nigeria including Mokwa Local Government of Niger State (Adoga and Obatomi, 1992). The competitiveness of Nigeria with regards to international trade in groundnut is significantly reduced because the crop is primarily susceptible to contamination by mycotoxins especially AFs and OTA and its contamination by AFs is severe (Makun *et al.*, 2012).

There are only three reports (Darling, 1963, Okonkwo and Nwokolo, 1978; Opadokun, 1992) on the incidence of AFs in groundnut in Niger State which is one of the major groundnut producing states in the country. More so, surveys on OTA content in nuts are very scarce in Nigeria. For Nigeria to improve its competitiveness in groundnut trade, the nation must generate data on mycotoxins in the crop so as to establish whether the levels are safe for human and animal consumption and further adopt measures to control their contamination levels. The current trend in climate change with its attendant influence on fungal contamination, mycotoxin production and distribution (Paterson and Lima, 2010) makes constant monitoring of food and feed an imperative in order to forestall outbreak of animal and human mycotoxicoses. It is for these reasons that this study was conducted to determine the incidence of AFB₁, AFB₂ and OTA in groundnut from Niger State in Nigeria.

2.0 Materials and Methods

2.1 Sampling

A total of 81 groundnut samples were randomly collected during the rainy season (August-September) from representative towns of twenty-five local government areas of Niger State. Based on the annual rainfall pattern, Niger State, a middle belt state of Nigeria has four microclimatic zones (Figure 2). Zones 1, 2, 3 and 4 are the wettest, wet, dry and driest zones with annual rainfall ranges (mm) of >1400, 1200-1400, 1000-1200 and <1000 respectively. Twenty of the samples were marketed roasted samples while 28 and 32 were collected from the store and farm respectively. With regards to sampling according to microclimatic zones, 22,

19, 19 and 21 were sampled from zones respectively. The stored samples were collected from locally built mud barns called "rumbu" in Hausa. About 0.5 kg of each sample were collected, labeled, packaged in small container and taken to the laboratory where they were ground to powder, put in sealed plastic bags and stored at -4°C until analysis.

2.2 Analysis of mycotoxins

Samples were subjected to extraction of toxins, clean up and analyzed for AFB₁, AFB₂ and OTA according to the method described by Ehrlich and Lee (1984) without modification. Methylene chloride and phosphoric acid were used for the simultaneous extraction of AFB₁, AFB₂ and OTA. A separate portion of the initial methylene chloride/phosphoric acid extract was subjected to a specific clean-up procedure for each mycotoxin.

2.2.1 Extraction of mycotoxins

Approximately 50 g portion of pulverized groundnut sample was weighed into a 500 ml Erlenmeyer flask and 25 ml 1M orthophosphoric acid and 250 ml of methylene chloride were added. The flask was placed on a mechanical shaker for 30 minutes and the content filtered under pressure on Buchner funnel fitted through an 18 cm circle rapid filter paper. Two hundred milliliter of the filtrate was collected and 50 ml aliquot was taken from the filtrate and placed in separate 100 ml Erlenmeyer flasks with glass stoppers, for AF and OTA assay.

The fraction for AFs analysis was subjected to a specific column chromatographic clean-up method. A column was set up with a glass wool and 150 ml of dichloromethane (DCM) was poured into the column and emptied half way. Anhydrous sodium sulphate (Na₂SO₄) was added and the sides of the column washed with DCM. Silica gel was added to the green line of column together with 80 ml of DCM and this was allowed to settle half way. Three scoops of anhydrous sodium sulphate (Na₂SO₄) were added and the DCM drained off to top of packed section of the column.

About 50 ml of the filtrate was added and drained off to top of the packed part of the column. The filtrate was defatted with 130 ml of hexane and 130 ml of ether sequentially, and each fraction drained out completely. Aflatoxins were extracted into 130 ml of ether/methanol/water (96:3:1, v/v/v) that was collected off column in a new beaker. The extract was evaporated to near dryness, put into sealed amber glass vials and stored at 0 °C for a week until further analysis.

A different clean-up method to that of aflatoxin was used for OTA. The toxin was extracted into aqueous solution of NaHCO₃ (4 g NaHCO₃/100 ml distilled water) and acidified to a pH of 2 with H₂SO₄ to obtain an acid fraction in a separatory funnel. Ochratoxin A was repeatedly extracted thrice from the acid fraction with 25 ml of DCM. The pooled DCM fraction was passed through anhydrous Na₂SO₄, evaporated to dryness and stored in sealed amber glass vials at 0 °C for a week until further analysis.

2.2.2 High Pressure Liquid Chromatography

Aflatoxins were analyzed on a Cecil 1100 series HPLC system equipped with a UV detector set at a wavelength of 365 nm as described by Cora, Angre and Ronald (2005). The Altaspher ODS column, 4.6 mm x 250 mm was used at ambient temperature of 25 °C. Acetonitrile/water/acetic acid (10:50:40, v/v/v) was used as the mobile phase pumped at a flow rate of 0.8 ml/min. The injection volume of both samples and standards used was 20 µl. The analysis was carried out with aflatoxin standards (Sigma Chemical Company, St. Louis, MO, USA) of known concentrations. Aflatoxin B₁ and AFB₂ eluted at distinct retention times of 1.673 min and 1.524 min, respectively. Calibration curves with correlation coefficient (R²) of 0.91 and 0.99 were established for AFB₁ and AFB₂, using a series of dilutions containing (0.004, 0.008, 0.012 and 0.016 µg/ml) and (0.01, 0.02, 0.03 and 0.04 µg/ml) respectively for each standard. The limits of

detection (LOD) were estimated as follows: known concentrations of aflatoxin standards were prepared, successively diluted and subjected to HPLC until the minimum concentration at which the analyte could be detected was established. The LOD of the HPLC instrument with regards to both toxins was determined to be 0.21 and 0.18 µg/kg while the limits of quantification (LOQ) were estimated based on the standard deviations of response and slope; this gave 0.42 and 0.33 µg/kg respectively.

OTA was quantified on same HPLC machine with a UV detector set at wavelength of 254 nm as described by Engstrom, Richard and Cysewski, (1977). The operating conditions were set at ambient temperature of 25 °C. Acetonitrile/water/acetic acid (50:48:2, v/v/v) was used as a mobile phase pumped at a flow rate of 1 ml/min. Injection volume of OTA analytes and standard was 60 µl. The retention time for OTA was 1.11 min. Calibration curve with an R² of 0.93 (Figure 10) was generated using series of dilutions containing 0.015, 0.025, 0.035 and 0.045 µg/ml. The LOD and LOQ for OTA were estimated to be 0.15 and 0.45 µg/kg respectively.

To determine the recoveries for the tested mycotoxins, 3 samples of each food commodity that were confirmed by same HPLC methods described above not to contain any of the studied mycotoxins were each spiked with 100 µg/kg of mycotoxin standard. For AFB₁ and AFB₂, the apparent recoveries (mean ± standard deviation) obtained were 93.6% ± 8.6 and 90.3% ± 8.5, respectively, while that of OTA was 97.5% ± 2.7.

2.3 Statistical analysis

Mean ± standard deviation and analysis of variance (students' t-test) of data generated were calculated using SPSS 18 software. The statistical level of significance was fixed at P<0.05 (95%).

Table 1: Incidence and concentration ($\mu\text{g}/\text{kg}$) of aflatoxin B₁ (AFB₁), AFB₂, and ochratoxin A in roasted, stored and farm groundnuts from Niger State

Mycotoxin	Incidence & concentration ($\mu\text{g}/\text{kg}$)	Roasted	Stored	Farm	Total
Aflatoxin B ₁	Incidence	19/21	25/28	28/32	72/81
	Mean \pm SE	64.78 ^a \pm 5.11	42.78 ^b \pm 4.27	54.32 ^c \pm 4.36	53.06 \pm 2.57
	Range	27.00 – 188.00	4.80 – 165.60	4.00 – 181.60	4.00 – 188.00
Aflatoxin B ₂	Incidence	16/21	19/28	26/32	61/81
	Mean \pm SE	11.60 ^a \pm 1.46	5.08 ^b \pm 0.81	8.10 ^{ac} \pm 0.99	8.08 \pm 0.63
	Range	0.40 – 36.40	0.80 – 32.80	0.40 – 38.40	0.40 – 38.40
Ochratoxin A	Incidence	19/21	24/28	30/32	73/81
	Mean \pm SE	13.30 ^a \pm 0.81	13.60 ^{ab} \pm 1.17	14.46 ^{abc} \pm 1.08	13.86 \pm 0.62
	Range	5.20 – 32.80	0.80 – 40.00	1.60 – 45.60	0.80 – 45.60

abc: Mean with different superscripts in a row are significantly different from each other ($p < 0.05$)

3.0 Results

The data (adjusted based on recovery) obtained from HPLC analysis as summarized in Table 1 shows the natural occurrence of AFB₁, AFB₂ and OTA in raw and roasted groundnut produced and marketed in Niger State, Nigeria. Generally, 88.9% of the samples were contaminated with aflatoxins (range = 0.4–188.0 $\mu\text{g}/\text{kg}$) with AFB₁ being more prevalent (incidence = 72/81 (88.9%)) and more concentrated (mean level: 53.1 $\mu\text{g}/\text{kg}$) in samples than AFB₂ (incidence = 61/81 (75.3%); mean level: 8.1 $\mu\text{g}/\text{kg}$). With respect to the type of samples collected (e.g. raw kernels from field or store, and roasted kernels from markets), AFB₁ increased in incidence from the farm (87.5%), to the store (89.3%) and market with roasting (90.5%) while the mean concentration decreased significantly ($p < 0.05$) from farm (54.3 $\mu\text{g}/\text{kg}$) to store (42.8 $\mu\text{g}/\text{kg}$) with a concomitant increase from store to market (64.8 $\mu\text{g}/\text{kg}$). However, the concentrations between the farm and market were significantly different at ($p < 0.05$) It was found that the highest incidence of AFB₂ was observed in farm samples (81.3%) followed by roasted marketed (76.2%) and stored samples (67.8%). However, based on the toxin content, AFB₂ occurred at the highest mean concentration of 11.6 $\mu\text{g}/\text{kg}$ in roasted groundnut samples followed by farm (8.1 $\mu\text{g}/\text{kg}$) and stored (5.1 $\mu\text{g}/\text{kg}$) samples and the differences were significant ($p < 0.05$).

Amongst the three mycotoxins analyzed, OTA occurred most frequently (73/81, 91%) in the samples and at moderate levels of 0.8–45.6 $\mu\text{g}/\text{kg}$ (Table 1). The incidence and levels of OTA were highest in samples from the farm (30/32 (93.8%); 14.46 $\mu\text{g}/\text{kg}$) followed by those from the store (24/28 (85.7 %); 13.60 $\mu\text{g}/\text{kg}$) and market (19/21 90.5 %); 13.30 $\mu\text{g}/\text{kg}$) although there were no significant differences in the levels of the toxin between sample categories. On a general note, higher mycotoxin (AFB₁, AFB₂ and OTA) incidences and concentrations were observed in the samples from open air sources (farm and market) than those from farmers' store. The only exception to this trend is the observed higher incidence of AFB₁ in stored samples than that found in farm samples.

The effects of annual rainfall intensity on mycotoxin contamination are reported in Table 2. Aflatoxin B₁ occurred most frequently (19/19, 100%) in samples from the dry zone, followed by those from the wet (17/19, 89.5%), wettest (19/22, 86.4%) and driest (17/22, 77.3%) zones. Similarly, samples from the dry zone had the highest AFB₁ mean level (74.0 $\mu\text{g}/\text{kg}$) followed by those from the driest (56.1 $\mu\text{g}/\text{kg}$), the wettest (45.1 $\mu\text{g}/\text{kg}$) and the wet (35.4%) zones. The AFB₁ concentrations of samples from the wet zone were significantly ($p < 0.05$) lower than levels of the toxin in the other zones. The frequency of occurrence of AFB₂ was also highest in samples from the dry zone (16/19, 84.2 %) while the lowest frequency was observed in samples from the

driest zone (14/21, 66.7%). The wet (15/19, 78.9%) had a higher frequency than the wettest zone (16/22, 72.7%). The mean AFB₂ content was higher in samples originating from the wettest zone (10.54 µg/kg) and dry (9.06 µg/kg) than those from driest (6.62 µg/kg) and wet (5.76 µg/kg) zones as seen in Table 2. However, the levels in the wet zone were significantly lower ($p < 0.05$) than those from the other zones. Ochratoxin A was recovered from 100% of samples from the dry and wet zones. Meanwhile 17/21 (81%) and 18/22 (81.8%) of samples from the driest and wettest zones were respectively found to be contaminated with OTA. However, with regards to contamination levels of the toxin, OTA was highest in samples from the wet (mean: 15.80 µg/kg) followed by the levels recovered from samples analyzed from the wettest (mean: 13.6 µg/kg), driest (mean: 13.5 µg/kg) and dry (mean: 12.6 µg/kg) zones. Based on the above observations, the general trend was that the incidence and levels of AFs and OTA contamination were lowest in extreme dry (driest zone) and wet (wettest zones) conditions. Accordingly, the highest concentrations of AFB₁ and OTA were observed in locations (Bida (range: 6.8-188.µg/kg and Borgu range 4.0-45.6µg/kg respectively) in the dry zone. while the lowest OTA concentration was detected in locations (Wushishi, range of 0.8 and 38.0µg/kg) in the driest part of the State

In addition, the study revealed co-occurrence of aflatoxins and ochratoxin A in 37/81 (45.7%) of the groundnut samples. Co-occurrence was detected in samples across all the zones evaluated in this study. Furthermore, 72/81 (88.9%) and 45/81 (55.6%) samples had AFB₁ and OTA concentrations above the Nigerian and European Union action limits of 2 µg/kg and 5 µg/kg, respectively.

4.0 Discussion

There are quite a few studies on aflatoxin contamination of groundnut and groundnut products from Niger State (Darling, 1963; Peers, 1965; Okonkwo and Nwokolo, 1978; Opadokun, 1992) in particular and Nigeria in general (Abalaka and Elegbede, 1982; Gbodi, 1986; Akano and Atanda, 1990; Bankole *et al.*, 2005; Odoemelam and Osu, 2009; Ezekiel *et al.*, 2012). However, except for Ezekiel *et al.* (2012) that reported the presence of 20 fungal metabolites including AFB, AFB₂, AFG₁, AFG₂ and OTA in 29 peanut cake samples analyzed by liquid chromatography tandem mass spectrometry (LC-MS/MS), all other investigations in the country were performed using the less sensitive and subjective thin layer chromatographic (TLC) technique. The detection limit of the LC/MS/MS used by Ezekiel *et al.* (2012) for ochratoxin A was 4.0 µg/kg making it less sensitive to the toxin than our method which had an LOD of 0.1 µg/kg.

Table 2: Incidence and concentration (µg/kg) of aflatoxin B₁ (AFB₁), AFB₂, and ochratoxin A in groundnuts in Niger State in accordance with rainfall pattern

Mycotoxin	Incidence & concentration (µg/kg)	Zone 4 (Driest)	Zone 3 (Dry)	Zone 2 (Wet)	Zone 1 (Wettest)	Total
Aflatoxin B ₁	Incidence	17/21	19/19	17/19	19/22	72/81
	Mean ± SE	56.10 ^a ± 5.11	74.02 ^b ± 5.94	35.44 ^c ± 4.25	45.10 ^{cd} ± 4.13	53.04 ± 2.57
	Range	8.00 – 165.60	5.60 – 188.00	4.00 – 13.60	6.40 – 141.60	4.00 – 188.00
Aflatoxin B ₂	Incidence	14/21	16/19	15/19	16/22	61/81
	Mean ± SE	6.62 ^a ± 1.10	9.06 ^{ab} ± 1.23	5.76 ^{abcd} ± 1.23	10.54 ^{abc} ± 1.47	8.08 ± 0.63
	Range	0.80 – 32.40	0.80 – 32.80	0.40 – 38.40	0.40 – 36.40	0.40 – 38.40
Ochratoxin A	Incidence	17/21	19/19	19/19	18/22	73/81
	Mean ± SE	13.50 ^a ± 1.4	12.64 ^{ab} ± 0.94	15.80 ^{abcd} ± 1.43	13.56 ^{abc} ± 1.23	13.88 ± 0.62
	Range	0.80 – 38.00	1.20 – 30.40	4.00 – 45.60	1.60 – 40.00	0.80 – 45.60

abc: Means with different superscripts in a row are significantly different from each other ($p < 0.05$)

The current study therefore presents for the first time the concentrations of aflatoxins and ochratoxin A in Nigerian groundnut using HPLC. The observed recoveries (above 90% for all studied toxins), LOD and LOQ indicate that the sensitivity and reliability of the methods employed were sufficient for evaluation of aflatoxins and OTA in groundnut. There is no report on OTA contamination of unprocessed groundnut in Nigeria; therefore, the present work to the best of our knowledge is the first survey on OTA in Nigerian groundnut. This survey has revealed that AFB₁, AFB₂ and OTA are common contaminants of raw and roasted groundnut. The observed higher incidence and levels of the studied mycotoxins in samples from open air sources (farm and market) than those from stores could be due to exposure of the nuts to favourable environmental conditions for fungal growth and mycotoxin synthesis in the field and at market than in the stores. High temperature and moisture conditions as well as floods experienced during the sampling period (rainy season of 2010) and the unwholesome transportation means coupled with adverse marketing practices in Africa can contribute to increased fungal proliferation and mycotoxin production (Wagacha and Muthomi, 2008), which might have resulted in increased levels of these toxins in field and marketed samples.

Optimal production of aflatoxins by *Aspergillus flavus* and *A. parasiticus* occurs at temperatures between 25 and 30 °C and kernel moisture content of about 18%, while optimal OTA production by *A. ochraceus* is attained at temperatures varying between 31 and 37 °C in grains with moisture content of 22% (Ominski *et al.* 1994). The above-mentioned conditions approximate to the ambient conditions in the dry and wet microclimatic zones under study (Umoh, 1997). The zones with extreme humid (wettest zone) and hot (driest zone) conditions are outside the optimal condition range hence may not be suitable for optimal mycotoxin production. It is thus not surprising that aflatoxins and OTA contamination of groundnut as reported in this work is more severe in the dry and wet zones than what

was observed in the wettest and the driest zone. This is in agreement with previous data reported by Atehnkeng *et al.* (2008) who found the mean aflatoxin concentration in maize from the humid Southern Guinea Savannah (mainly from Bida) to be higher than those from drier, hotter North Guinea Savannah and the very humid, cooler Derived Savannah of Nigeria.

The absolute levels of aflatoxins reported in the present study are comparable to those observed by Bankole *et al.* (2005) in roasted groundnut (range: 5–165 µg/kg for AFB₁) and Odoemelam and Osu (2009) in raw groundnut (range: 74.03–82.12 µg/kg for AFB₁) but much lower than those reported by Darling (1963) (range: 100–2000 µg/kg), Peers (1965) (range: 100–2000 µg/kg), Okonkwo and Nwokolo (1978) (max: 900 µg/kg), Abalaka and Elegbede (1982) (max: 600 µg/kg), and Opadokun (1992) (max: 8000 µg/kg). Additionally, aflatoxin concentrations reported herein were much lower than the levels found in Nigerian groundnut cake: 20–455 µg/kg (Akano and Atanda, 1990) and 13–2824 µg/kg (Ezekiel *et al.*, 2012).

The extremely high levels of aflatoxins found in the raw and roasted forms of Nigerian groundnut that were above the Nigerian and European Union (EC, 2002) maximum acceptable limits for AFB₁ is of serious public health concern considering that the nut is regularly consumed by the population and the cake used as an inevitable source of protein in animal feed formulations. Of grievous concern is the fact that these highly aflatoxin contaminated products are consumed mostly by school aged children and young adults (Ezekiel *et al.* 2013) who are still in active reproductive and labour ages. Exposure therefore to aflatoxins at such unsafe levels by these vulnerable groups could synergically act with other carcinogens, especially hepatitis B virus, to elicit the high incidence of primary liver cancer observed among the Nigerian population (Olubuyide and Solanke, 1990).

Reports on OTA contamination of foods from Nigeria are only on cocoa and cocoa products (Bankole and Adebajo, 2003) maize (Gbodi, *et al.* 1986; Adebajo *et al.* 1994), maize-based weaning food (Oyelami *et al.* 1996), sorghum

(Elegbede *et al.* 1982; Makun *et al.* 2009), rice (Makun *et al.* 2007; Ayejuyo *et al.* 2008; Makun *et al.* 2011), kolanut and cocoa bean (Bankole and Adebajo, 2003) and tiger nut (Adebajo, 1993) but none exists for groundnut in the country. The high presence of OTA in over 90% of the samples with more than one half of the samples having unsafe levels of the nephrotoxin could impact negatively on human (Reddy and Bhoola, 2010) and animal health (Battacone *et al.* 2010). The nephrotoxin has long retention time in serum of pigs and other animals and therefore is persistent carryover of the toxin into edible animal tissues and products (Duarte, Lino and Pena. 2011). This associated public health impact might be aggravated in Nigeria with such high OTA prevalence.

The implications of the simultaneous occurrence of mycotoxins within the same food matrix as shown in this work to human and animal health is complex. However, it has been established that the interactive effects of mycotoxins in combinations could be synergistic, additive or antagonistic in the host organism (Miller, 1995; Speijer and Speijer, 2004). Co-occurrence of AFB₁ and OTA could be synergistic in causing nephropathy and increasing the mutagenic effect of the latter (Sedmikova *et al.* 2001). The anticipated adverse public health impact that could result from exposure to aflatoxins and OTA, singly or in combination, should necessitate the regulation of mycotoxins by the relevant agencies in Nigeria. More so, such enforcement of legislation against mycotoxins will improve Nigeria's access to high-value international trade markets. There is also the need for intensive public enlightenment on the hazards of mycotoxins to farmers and traders of agricultural products in the country.

Acknowledgement

The authors are grateful to Pius Ikokoh of Sheda Science and Technology Complex (SHESTCO), Abuja, Nigeria for the HPLC analysis.

Conflict of Interest: There is no conflict of interest on the work

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