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Original Research Article

Study on Total Aflatoxin Contents of Wheat Sold in Kaduna and Kano States, North–West, Nigeria

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Abstract

This study was designed to assess the total aflatoxin (B_1, B_2, G_1, and G_2) contents in twenty two samples of wheat (eleven foreign produced and eleven local produced) that are sold in some selected markets in Kaduna and Kano States, North West Nigeria. Samples were collected using a simple random sampling technique and analyzed using an AgraQuant Total Aflatoxin Assay which is an enzyme-linked immunosorbent assay (ELISA) method. Aflatoxins were extracted from a ground samples with 70% methanol. The extracted samples and enzyme-conjugated aflatoxins were mixed and added to the antibody-coated microwell. Aflatoxins in samples and control standards were allowed to compete with enzyme-conjugated aflatoxin for the antibody binding site. The22 samples studied had average total aflatoxin content of 0.58 µg/kg and conforms to the Codex Alimentarius maximum limit of 10 µg/kg and to the EU, Commission Regulations (EC) No 2174/2003 and (EC) No 1881/2006 maximum limit of 4 µg/kg for not-ready to eat foods. One (4.2 µg/kg) of the 11 foreign produced wheat samples exceeded the EU maximum limit. Consumption of wheat grains, a staple Nigerian diet, may therefore expose the population to aflatoxin contamination. Hence, there is need for an immediate action plan for aflatoxin awareness in Nigeria; in view of the economic and public health importance of the toxins. Appropriate regulatory bodies in Nigeria should stipulates and enforces action levels of aflatoxin in food and feed intended for human and animal consumption with the aim of protecting the health of the consumer and safeguarding the health of the nation.

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Keywords

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Introduction

Aflatoxins are a group of extremely toxic and carcinogenic metabolites produced by the common fungi *Aspergillus flavus* and *Aspergillus parasiticus*, which grow on plants and food of vegetable origin. Aflatoxins are fluorescent compounds with a condensed coumarinic structure with one bifurane and one pentanone (aflatoxin B) or one lactone (aflatoxins G) group. The letters B and G refer to the colour of the aflatoxin under ultraviolet light (Blue and Green), and the numbers 1 and 2 refer to their position in chromatographic separation (AESAN, 2011). A study conducted by Williams et al. (2004) indicated that much

of Sub-Saharan Africa is at risk of unsafe levels of aflatoxin exposure that can negatively affect human health, food security and economic trade. It has been reported by Jolly et al., (2013) to be immunosuppressive in animal and human studies. The toxins build up in staple food crops mainly during postharvest handling and storage under hot and humid climatic conditions (Milani, 2013; Jolly et al., 2013). Mycotoxicosis is a disease that results from the ingestion of food contaminated with mycotoxins (Doolotkeldieva, 2010).

The more relevant aflatoxin in terms of food safety are B_1 and B_2 (produced by *A. flavus* and *A. parasiticus*), G_1 and G_2 (produced by *A. parasiticus*) and M_1 and M_2 (metabolites of aflatoxin B_1 and B_2 which are excreted in milk). Among them, aflatoxin B_1 stands out from a health safety point of view as it is the most common in food as well as the most toxic for humans (Deng et al., 2010).

Prevention of mycotoxin contamination of human food will improve economic sustainability, enhance food quality and safety efforts, enhance international trade, and improve public health (Murphy et al., 2006). Mycotoxins are often found as contaminants in agricultural products before or after harvest as well as during transportation or storage. Therefore, they can significantly decrease the quality of wheat and reduced livestock productivity (Čonková et al., 2006; Murphy et al., 2006).

In Nigeria, agricultural products are mostly produced by small-scale farmers and the products sold in local markets (Bandyopadhyay et al., 2007). Since these products rarely enter official channels of sales, surveillance of the level of aflatoxin contamination rarely happens (Adetunji et al., 2014).

This study is concerned with the quality and safety of food. Sub-Saharan Africa is an aflatoxin endemic region with fewer infrastructures for mycotoxin detection (Shephard, 2003; Williams et al., 2004; Atanda et al., 2014). In a study conducted by El-Shanshoury et al. (2014) reported that; a number of countries have conducted surveys on the incidence of mycotoxins in their agricultural products. Most of these surveys were concerned with occurrence of aflatoxins; thus, this research effort in North-West Nigeria. The Food and Agricultural Organization of the United Nations (FAO) estimated that at least 25% of the world's cereal grains are contaminated by mycotoxins, including aflatoxin (FAO, 2003). Aflatoxin can contaminate agricultural commodities including corn, wheat, rice, peanut, and many other crops (Aly, 2002; Reddy et al., 2009; Yassin et al., 2011; El-Shanshoury et al., 2014).

With the levels of grain contamination, consumption of wheat grains, a staple Nigerian diet, may therefore expose the population to mycotoxin contamination. There is need for an immediate action plan for mycotoxin mitigation in Nigeria, in view of the economic and public health importance of the toxins (Adetunji et al., 2014).

Information on the occurrence, distribution and concentration of the contaminated grains will benefit food safety initiatives and enhance necessary interventions by relevant regulatory and health agencies in Nigeria. Hence, this study that is aimed to assess the quality and safety of wheat by determining the presence and levels of aflatoxin content in Wheat sold in Kaduna and Kano States, North West Nigeria.

Materials and methods

Study area

Kaduna and Kano States are located in the Northern Guinea Savanna and Sudan Savanna agro-ecological zones of Nigeria respectively (Adetunji et al., 2014). Wheat is cultivated locally in Kano State at the Kadawa River Irrigation Project, located at lat. $11^0$39'N, long. $08^0$27'E and 500 m above sea level (Falaki and Mohammed, 2011).

Collection of samples

Sampling was done from July 20, 2015 to August 3, 2015. Samples collected were of two varieties; foreign produced wheat (Hard Red Winter) and local produced wheat (Durum). Simple random sampling technique was applied and composite samples of 3 kg of each variety were collected in each market according to Adetunji et al. (2014) in Kaduna and Kano States, North West Nigeria.

Total samples were 22, namely: Monday Market 1 (MND_1), Monday Market 2 (MND_2), Zaria Market1 (ZRA_1), Zaria Market 2 (ZRA_2), Kafanchan Market1 (KAF_1), Kafanchan Market 2 (KAF_2), Brigade Market 1 (BGD_1), Brigade Market 2 (BGD_2), Dawanu Market 1 (DWN_1), Dawanu Market 2 (DWN_2), Chiromawa

Market 1 (CMW_1), Chiromawa Market 2 (CMW_2), Kawo Market 1 (KWO_1), Kawo Market 2 (KWO_2), Saminaka Market 1 (SMK_1), Saminaka Market 2 (SMK_2), SabonGari Market 1 (SBG_1), SabonGari Market 2 (SBG_2), Sharada Market 1 (SRD_1), Sharada Market 2 (SRD_2), Sabon Tasha Market 1 (SBT_1), and Sabon Tasha Market 2 (SBT_2). The samples were hand-mixed and transported in well labeled sterile polythene bags.

Sample analysis was done at the Mycotoxins and Pesticides Laboratory Unit of the National Agency for Food, Drug Administration and Control (NAFDAC) Area Laboratory, Kaduna, Nigeria.

Preparation/Extraction of samples

Sample preparation and extraction was done using Romer Labs Method #: Pl-000051-1, 2012 with little modification.

1. 500 g was obtained from each representative (composite) sample and was grinded using a Warring Commercial Blender HGB2WTG4.
2. 20 g of the ground sample was weighed using a Sartarius ED224S (Max 220 g) balance into a clean glass Pyrex Extraction Bottle 250 ml.
3. 100 ml of 70/30 (v/v) methanol/water extraction solution was added. Samples were extracted in the ratio of 1:5 (w:v) of sample to extraction solution respectively.
4. The samples were vigorously shaken for 3 minutes using an Orbital Shaker DS2-5002 by VWR.
5. Samples were allowed to settle and the top layer of extract was filtered using a Whatman #1 filter, the filtrate was collected in a clean glass tube.

Assay

1. 28 green-bordered dilution strips were placed in a microwell strip holder. One dilution well was used for each standard (0, 1.0, 2.0, 4.0, 10.0, and 20.0 ppb) (see plate 4) and one dilution well for each sample (MND_1, MND_2, ZRA_1, ZRA_2, KAF_1, KAF_2, BGD_1, BGD_2, DWN_1, DWN_2, CMW_1, CMW_2, KWO_1, KWO_2, SMK_1, SMK_2, SBG_1, SBG_2, SRD_1, SRD_2, SBT_1, and SBT_2).
2. An equal number of antibody coated microwell strips were placed in a microwell strip holder.
3. 200 µl of conjugate (green capped bottle) was dispensed into each green-bordered dilution well.
4. Using a single channel Eppendorf Research Pipettor, 100 µl of each standard was added to the first 6 green-bordered dilution wells. A fresh pipette tip was used for each Standard. Pipettes tips were completely empty.
5. Using a single channel Eppendorf Research Pipettor, 100 µl of each sample was added to the next 7–28 green-bordered dilution wells containing 200 µl of conjugate. A fresh pipette tip was used for each sample. Pipettes tips were completely empty.
6. An 8-channel Eppendorf Research Pipettor with fresh tips was used each time for 8-well strip; each well was mixed by carefully pipetting it up and down 3 times and immediately transferred 100 µl of the contents of each dilution well into a corresponding antibody coated microwell.
7. The antibody coated microwell was incubated at room temperature for 15 minutes using a Fisher Scientific No. 2025 051 Timer. Antibody coated microwell was not agitated as this will cause well-to-well contamination.
8. Contents of the microwell strips were emptied into a waste container. Each microwell strip was washed by filling each microwell strip with deionized water, and then dumping the water from the microwell strips. This step was repeated 4 times for a total of 5 washes. Care was taken not to dislodge the Strips from the Holder during the wash procedure.
9. After the fifth wash, several layers of absorbent towels was placed on a flat surface on the work bench, and microwell strips were tapped on the towel to expel as much residual water as possible. The bottoms of the microwell strips were dried with a clean paper towel.
10. 100 µl of substrate was measured from the blue-capped bottle into each microwell strip using a single channel pipettor; a fresh tip was used for each microwell strip. It was incubated at room temperature for 5 minutes using a Fisher Scientific No. 2025 051 Timer.
11. 100 µl stop solution was measured from the red-capped bottle using a single channel pipettor and dispensed into each microwell strip. A color change from blue to yellow was observed.
12. The Strips were read with a Stat Fax ELISA Reader Model 303 Plus, using a 450 nm filter and differential filter of 630 nm. The Optical Density (OD) for each Microwell was read and

printed. Air bubbles were eliminated prior to reading the strips as it may affect analytical results.

Results

The results of the AgraQuant total aflatoxin assay 1/20 for the 22 samples were read and printed using a Stat Fax ELISA Reader Model 303 Plus.

Table 1. Absorbance and total aflatoxins content of samples studied in Strip 'A'.

S/N	Name of sample	Well		Abs	ppb or µg/kg
	Strip: A	**Carrier position A**			
1	STD	1	C1	0.889	0.0
2	STD	2	C2	0.675	1.0
3	STD	3	C3	0.698	2.0
4	STD	4	C4	0.501	4.0
5	STD	5	C5	0.169	10.0
6	STD	6	C6	0.127	20.0
1	MND_1	7	1	0.768	0.0
2	MND_2	8	2	0.632	2.7

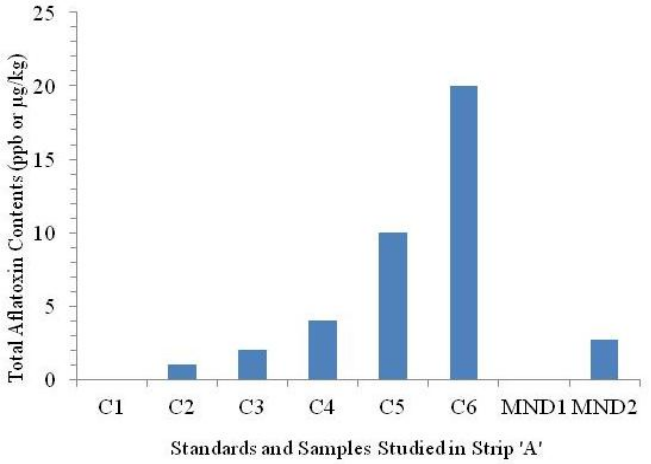

Fig. 1: Total aflatoxin content of samples studied in Strip 'A'.

Table 1 and Fig. 1 shows absorbance and total aflatoxin content of samples studied in Strip 'A'; Standards: C1 had an absorbance of 0.889 and total aflatoxin content of 0.0 µg/kg, C2 had an absorbance of 0.675 and total aflatoxin content of 1.0 µg/kg, C3 had an absorbance of 0.698 and total aflatoxin content of 2.0 µg/kg, C4 had an absorbance of 0.501 and total aflatoxin content of 4.0 µg/kg, C5 had an absorbance of 0.169 and total aflatoxin content of 10.0 µg/kg, C6 had an absorbance of 0.126 and total aflatoxin content of 20.0 µg/kg, and Test Samples: MND_1 had an absorbance of 0.768 and total aflatoxin content of 0.0 µg/kg, and MND_2 had an absorbance of 0.632 and total aflatoxin content of 2.7 µg/kg. Fig. 2 shows the concentration of standards (C1-C6) and the levels of total aflatoxin content of samples (MND_1 and MND_2) studied in strip 'A'.

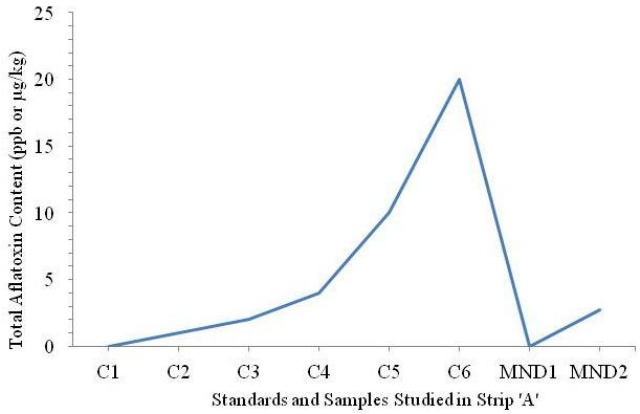

Fig. 2: Total aflatoxin content of samples studied in Strip 'A'.

Table 2. Absorbance and total aflatoxin content of samples studied in Strip 'B'.

S/N	Name of sample	Well		Abs	ppb or µg/kg
	Strip: B	**Carrier position B**			
3	ZRA_1	1	7	0.821	0.0
4	ZRA_2	2	8	0.762	0.0
5	KAF_1	3	9	0.795	0.0
6	KAF_2	4	10	0.747	0.0
7	BGD_1	5	11	0.752	0.0
8	BGD_2	6	12	0.747	0.0
9	DWN_1	7	13	0.751	0.0
10	DWN_2	8	14	0.662	1.9

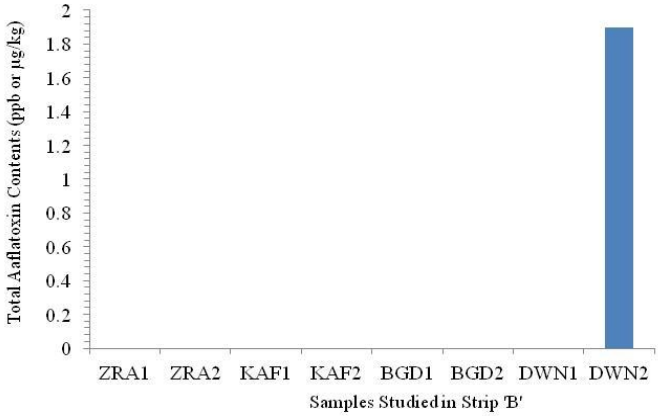

Fig. 3: Total aflatoxin content of samples studied in Strip 'B'.

Table 2 and Fig. 3 shows absorbances and total aflatoxins content of samples studied in Strip 'B': ZRA_1 had an absorbance of 0.821 and total aflatoxin content of 0.0 µg/kg, ZRA_2 had an absorbance of 0.762 and total aflatoxin content of 0.0 µg/kg, KAF_1 had an absorbance of 0.795 and total aflatoxin content of 0.0 µg/kg, KAF_2

had an absorbance of 0.747 and total aflatoxin content of 0.0 µg/kg, BGD_1 had an absorbance of 0.752 and total aflatoxin content of 0.0 µg/kg, BGD_2 had an absorbance of 0.747 and total aflatoxin content of 0.0 µg/kg, DWN_1 had an absorbance of 0.751 and total aflatoxin content of 0.0 µg/kg, DWN_2 had an absorbance of 0.662 and total aflatoxin content of 1.9 µg/kg. Fig. 4 shows the levels of total aflatoxin content of samples studied in strip 'B'.

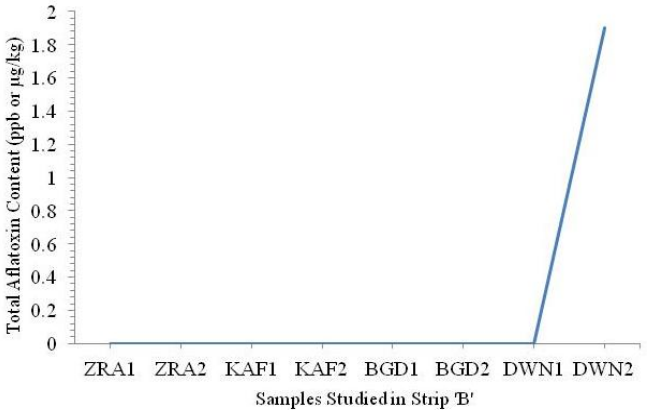

Fig. 4: Total aflatoxin content of samples studied in Strip 'B'.

Table 3. Absorbance and total aflatoxin content of samples studied in Strip 'C'.

S/N	Name of sample	Well		Abs	ppb or µg/kg
	Strip: C	**Carrier position C**			
11	CMW_1	1	19	0.754	0.0
12	CMW_2	2	20	0.697	0.9
13	KWO_1	3	21	0.776	0.0
14	KWO_2	4	22	0.741	0.0
15	SMK_1	5	23	0.730	0.0
16	SMK_2	6	24	0.706	0.7
17	SBG_1	7	25	0.737	0.0
18	SBG_2	8	26	0.644	2.4

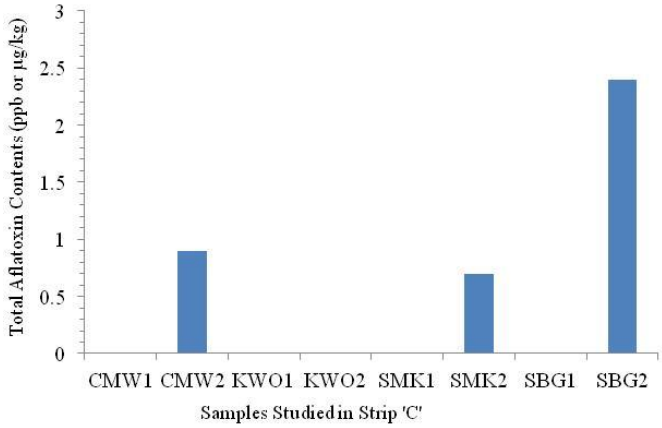

Fig. 5: Total aflatoxin content of samples studied in strip 'C'.

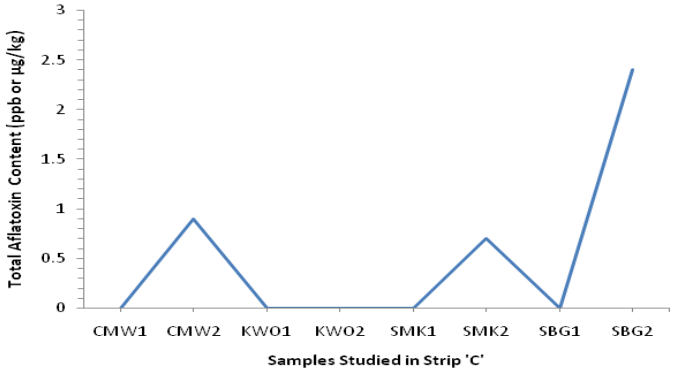

Fig. 6: Total aflatoxin content of samples studied in strip 'C'.

Table 3 and Fig. 5 show absorbances and total aflatoxins content of samples studied in Strip 'C': CMW_1 had an absorbance of 0.754 and total aflatoxin content of 0.0 µg/kg, CMW_2 had an absorbance of 0.697 and total aflatoxin content of 0.9 µg/kg, KWO_1 had an absorbance of 0.776 and total aflatoxin content of 0.0 µg/kg, KWO_2 had an absorbance of 0.741 and total aflatoxin content of 0.0 µg/kg, SMK_1 had an absorbance of 0.730 and total aflatoxin content of 0.0 µg/kg, SMK_2 had an absorbance of 0.706 and total aflatoxin content of 0.7 µg/kg, SBG_1 had an absorbance of 0.737 and total aflatoxin content of 0.0 µg/kg, SBG_2 had an absorbance of 0.644 and total aflatoxin content of 2.4 µg/kg. Fig. 6 shows the levels of total aflatoxin content of samples studied in strip 'C'.

Table 4. Absorbance and total aflatoxin content of samples studied in strip 'D'.

S/N	Name of sample	Well		Abs	ppb or µg/kg
	Strip: D	Carrier position D			
19	SRD_1	1	31	0.579	4.2
20	SRD_2	2	32	0.752	0.0
21	SBT_1	3	33	0.750	0.0
22	SBT_2	4	34	0.767	0.0

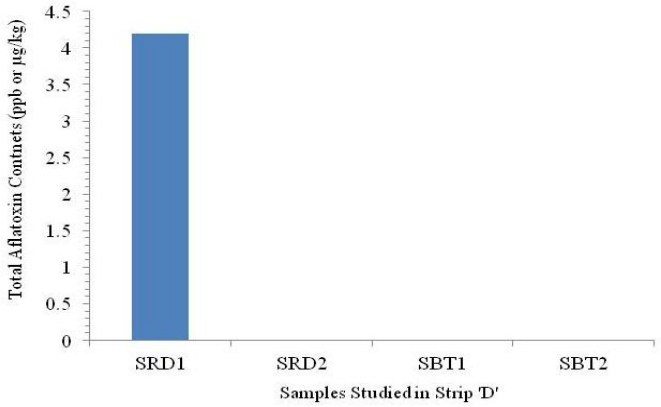

Fig. 7: Total aflatoxin content of samples studied in strip 'D'

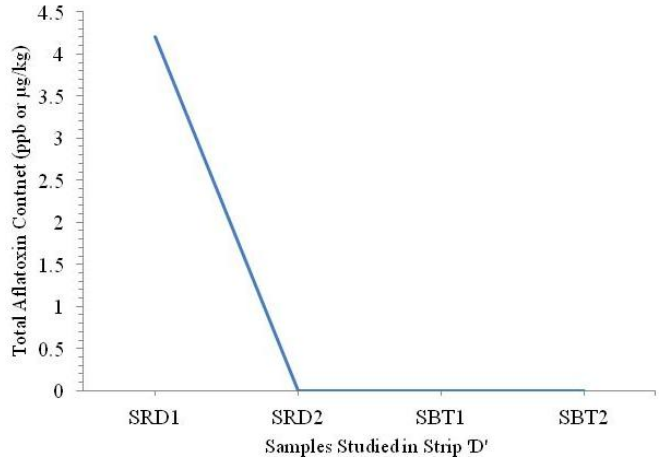

Fig. 8: Total aflatoxin content of samples studied in strip 'D'.

Table 4 and Fig. 7 shows absorbances and total aflatoxin content of samples studied in Strip 'D': SRD_1 had an absorbance of 0.579 and total aflatoxin content of 4.2 µg/kg, SRD_2 had an absorbance of 0.752 and total aflatoxin content of 0.0 µg/kg, SBT_1 had an absorbance of 0.750 and total aflatoxin content of 0.0 µg/kg, and SBT_2 had an absorbance of 0.767 and total aflatoxin content of 0.0 µg/kg. Fig. 8 shows the levels of total aflatoxin content of samples studied in strip 'D'.

Discussion

A total of twenty two (22) samples were studied. These samples were made up of two distinct wheat variety (foreign produced and local produced) commonly sold in markets in Kaduna and Kano States, North-West Nigeria. Of the 22 samples, foreign produced and local produced wheat varieties had a total of 11 samples each. All foreign produced samples were coded based on the name of the market in which it was collected and marked with a subscript 1 while all local produced samples were coded based on the name of the market in which it was collected and marked with a subscript 2, therefore, all samples with subscript 1 are foreign produced and all samples with subscript 2 are local produced.

The international regulatory total aflatoxin action limits used in this study to bench-marked results obtained are the Codex Alimentarius total aflatoxin maximum limit for not-ready to eat food of 10 µg/kg (Codex Alimentarius, 2008), and the European Union Commission total aflatoxin maximum limit for not-ready to eat food of 4 µg/kg (EU, 2003; 2006). The not-ready to eat food is a phrase used by the National Agency for Food, Drug Administration and Control (NAFDAC), this agency enforces compliance of Producers, Marketers, Manufacturers and Industries to food and drug standards that are stipulated by the Standard Organization of Nigeria (SON) in order to safeguard and protect the health of the consumer. SON is a Member of the International Organization for Standardization (ISO).

Ten (90.91%) of the foreign produced wheat samples studied had total aflatoxin content of 0.0 µg/kg, while 1(9.09%) wheat sample had a total aflatoxin content of 4.2 µg/kg. 6(54.55%) of the local produced wheat had a total aflatoxin content of 0.0 µg/kg, while 5(45.45%) wheat samples had total aflatoxin content of 2.7 µg/kg, 1.9 µg/kg, 0.9 µg/kg, 0.7 µg/kg, and 2.4 µg/kg.

Sixteen (72.70%) of the 22 samples had total aflatoxin content of 0.0 µg/kg, while 6 (27.30%) of the 22 samples had total aflatoxin content of 2.7 µg/kg, 1.9 µg/kg, 0.9 µg/kg, 0.7 µg/kg, 2.4 µg/kg, and 4.2 µg/kg.

These results revealed low levels of total aflatoxin content in the samples studied and it correlates with results of earlier similar studies conducted on wheat in other countries. In a study reported in year 2000 in India, out of 223 samples collected in wheat growing belt of western U. P. (India), only 9 samples were found contaminated from aflatoxin B in the range of 8-40 ppb. In 1985, the entire 6 flood affected wheat samples collected from Punjab were found contaminated with aflatoxin B_1in the range of 8-40 ppb (Goyal, 2000).

More agreeably are the following studies; a survey of various mycotoxins was carried out on samples of wheat delivered to nine storage and marketing depots in south-eastern Queensland. Aflatoxins B_1, B_2, G_1, and G_2 were detected in only one pooled of wheat, at a total aflatoxins concentration of 0.003 mg/kg (Blaney et al., 2005). Experimental study was done to determine total aflatoxin content of Iranian wheat and variation of them after storage. The results showed that: at first step of sampling, total aflatoxins were detected in only three samples at amounts 0.23, 0.22, 0.53 ppb. At the second stage, total aflatoxins were detected in just two samples at amounts 0.15, 0.10 ppb. According to the results of this study, contaminated wheat with aflatoxins was very low and the amount of aflatoxins wasn't increase during storage (Dastmalchi, 2008). Another study in 2012 to determined aflatoxin level in Wheat flour samples in the Golestan province, north of Iran was investigated. Mean

total aflatoxin levels of samples were 0.82 and 1.99 ng/g in summer and winter, respectively. Aflatoxin B_1 levels were detected in 3.1%, 7.4% over permissible limits by worldwide regulations in samples collected in summer and winter, respectively. Aflatoxins in winter were higher than summer. The highest frequency of aflatoxin contamination in winter was B_2 (98%) and in summer G_1 (51%) (Taheri et al., 2012).

In Nigeria, the researcher found out that from literature review with particular reference to wheat, no studies on total aflatoxin levels in wheat have been reported, but many documented and reported studies exist on studies on total aflatoxin levels in maize and feed. All studies from Nigeria reported in this study revealed very high levels of contamination in finished feed that do not meet Standard Organization of Nigeria (SON) guidelines for human or animal consumption (Abt Associates, 2012). A study in Nigeria of groundnut cake in 1990 destined for animal feed in the Ibadan market contained between 20 µg/ppb and 455 µg/ppb of aflatoxin B_1 (Akano and Atanda, 1990). In year 2000, a study in Nigeria found aflatoxins in "alarming concentrations of between 3, 000 to 138, 000 µg/kg in pre-harvest maize samples" (Maxwell et al., 2000). In 2008, another study of 55 maize samples collected from 11 districts of three agro-ecological zones of Nigeria showed that in 10 of the 11 districts, samples were found with aflatoxin levels of 30.9-507.9 µg/kg (Atehnkeng et al., 2008). An investigation in 2010 of 13 samples of poultry feed in Nigeria found a mean concentration of 15.5 ppb with a range of 0 to 67.9 ppb (Adebayo-Tayo and Etta, 2010).

A recent study in 2012 found that 90% of groundnut cake samples from five states in Nigeria had aflatoxin levels that exceeded 20 ppb (Ezekiel et al., 2012). Groundnut cake is a preferred ingredient in animal feed due to its relatively cheap protein source, is very susceptible to high levels of aflatoxin contamination.

The above reported studies from Nigeria agreed with earlier studies done by Aldred and Magan, 2004 that cereals are probably the most important source of intake of mycotoxins. Aflatoxins are associated with a wider range of food commodities, but significant amounts of aflatoxins may occur in maize. Today, it is normal to detect mycotoxins in wheat samples, but usually at levels that are not currently considered to present an acute health hazard. However, it must be acknowledged that globally the potential for problems certainly exists within the production system (Aldred and Magan, 2004).

The total aflatoxin content of 6(27.27%) wheat samples with 2.7 µg/kg, 1.9 µg/kg, 0.9 µg/kg, 0.7 µg/kg, 2.4 µg/kg, and 4.2 µg/kg of the 22 wheat samples studied were all in conformity with the maximum limit of total aflatoxin content of 10 µg/kg of the CODEX Alimentarius 2008 maximum limit for not-ready to eat food; therefore, all the 22 wheat samples (foreign and local) studied for total aflatoxin content were all in conformity to the CODEX Alimentarius maximum limit for not-ready to eat food (10 µg/kg).

Of the 6(27.27%) local produced and foreign produced wheat samples, only 1(4.55%) sample with total aflatoxin content of 4.2 µg/kg(foreign produced wheat) exceeded the maximum limit of 4 µg/kg in the EU 2003 and 2006 maximum limit for not-ready to each food, was not in conformity to the EU maximum limit for not-ready to eat food; therefore, 21(94.45%) wheat samples (foreign produced and local produced) conformed to the EU maximum limit for not-ready to eat food.

The results of this study shows low levels of total aflatoxin content ranging from 0.0 – 2.7 µg/kg or ppb in local produced wheat and total aflatoxin content ranging from 0.0 – 4.2 µg/kg or ppb in foreign produced wheat. These results correlates with earlier similar studies of Blaney et al., 2005; Dastmalchi, 2008; Taheri et al., 2012 on total aflatoxin content in wheat conducted in other countries around the globe.

Conclusion

Local and foreign produced wheat sold in Kaduna and Kano States, North West Nigeria has high Total Aflatoxin Contents and do not meet national and international regulatory limits.The22 samples studied had average total aflatoxin content of 0.58 µg/kg. Null hypotheses one was therefore rejected by both CODEX Alimentarius maximum limit for not-ready-to-eat food of 10 µg/kg and the EU maximum limit of 4 µg/kg for not-ready-to-eat food.

Local and foreign produced wheat sold in Kaduna and Kano States, North West Nigeria has low Total Aflatoxin Contents and meet national and international regulatory limits.The22 samples studied had average total aflatoxin content of 0.58 µg/kg. Null hypotheses two was therefore accepted by both CODEX Alimentarius maximum limit for not-ready-to-eat food of 10 µg/kg and the EU maximum limit of 4 µg/kg for not-ready-to-eat food. However, one (9.09%) of the 11

foreign produced wheat samples had total aflatoxin content of 4.2 µg/kg and was rejected by the EU maximum limit of 4µg/kg for Not-ready-to-eat food and accepted by the CODEX Alimentarius maximum limit of 10 µg/kg for not-ready-to-eat food.

Recommendation

It is strongly recommend that further research should be done on this topic with emphasis on the analysis of the fractions of aflatoxin (B_1, B_2, M_1, M_2, G_1 and G_2) using the High Power Liquid Chromatography (HPLC) technology.

Study area should include the local wheat producing States in Nigeria, namely: Adamawa, Bauchi, Borno, Jigawa, Kano, Katsina, Kebbi, Yobe, Sokoto, and Zamfara States in the Sudan/Sahelian agro-ecological zones of Nigeria.

More aflatoxin studies should be encouraged in Northern Nigeria by the indigenous people as current studies from this part available to the world in the World Wide Web have been done by authors from the Western and Eastern Nigeria.

Flour mills and wheat product manufacturing industries should collaborate with government, relevant agencies and universities to sponsor studies on mycotoxins as the cost of these studies are very expensive and often discouraged good will students who are financially not buoyant.

Conflict of interest statement

Authors declare that they have no conflict of interest.

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