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Research Article

Survey of Knowledge on Moulds and Aflatoxin Contaminations of Grains Sold in Major Markets for Human Consumption within North-Central-States Capital Cities, Nigeria

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ABSTRACT

Aflatoxins, categorised as carcinogenic mycotoxins, were studied in grains sold for human consumption across North-Central Capital Cities from December 2022 to November 2023. The survey encompassed six cities (Jos, Minna, Markurdi, Lafiya, Lokoja, and Ilorin) and utilised structured questionnaires to gather data. Knowledge levels regarding mould infections and aflatoxins contamination were assessed using descriptive statistics, while demographic influences were analysed via independent t-tests. Results indicated that 32.5% to 42.5% of respondents identified mould infections in grains, while 34.2% to 90.8% were unaware of aflatoxin's association with liver cancer. Notably, females demonstrated higher knowledge and mean scores (79.67±5.20) compared to males (40.33±5.20). Individuals with ≥ secondary education exhibited greater understanding and mean scores (91.67±7.12) than those with less than secondary education (24.50±6.95), and respondents aged > 33 years scored higher (84.17±7.28) than those aged ≤ 33 years (29.33±7.39). Aflatoxin contamination levels exceeded the European limit (not greater than 4.0 µg/kg) in 11.7% of samples, with statistically no significant differences observed ($p > 0.05$). The findings underscore the importance of regional enlightenment campaigns regarding mould infections in grains and the health risks associated with aflatoxins for both humans and animals. Such initiatives are crucial for enhancing public awareness and promoting practices that mitigate aflatoxin exposure, ultimately safeguarding human and animal health within the surveyed area.

Keywords: Knowledge; Moulds; Aflatoxins; Grains

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INTRODUCTION

Aflatoxins are mycotoxins produced through a biological pathway (Yu *et al*., 2004; Juan *et al*., 2008) by two vital aflatoxigenic strains: *Aspergillus flavus* and *Aspergillus parasiticus* (Klich *et al*., 2000; El-Khoury *et al*., 2011; Shitu *et al*., 2018). They are produced by certain strains of moulds as secondary metabolites, which represent a serious risk for human and animal health (Noelia *et al*., 2011; Jianglin *et al*., 2022). Uncommon aflatoxin producers have additionally been reported (Horn, 2007). These aflatoxigenic species were stated to have one-of-a kind toxigenic profiles: *Aspergillus flavus* produces aflatoxin B1 (excreted in breast milk as M1) (Álvarez-Días *et al*., 2022), B2, cyclopiazonic acid, aflatrem, 3-nitropropionic acid, sterigmatocystin, and versicolorin A; and aspertoxin, *Aspergillus parasiticus* produces aflatoxin B1, B2, G1, G2, and versicolorin A (Mathew *et al*., 2017).

Usually, aflatoxin B1 is predominantly the most toxic, potent genotoxic metabolite, and hepatocarcinogenic to man. More so, aflatoxin B1 is classified by the International Agency for Research on Cancer (IARC) as a human group-one carcinogen (IARC, 2002). The occurrence of aflatoxin has been reported to occur primarily through the ingestion of contaminated foods or animal feed, and to some degree, through skin contact. Aflatoxicosis is the common name given to diseases caused by aflatoxin consumption. There are two types of aflatoxicosis: acute aflatoxicosis, which results in death, and chronic aflatoxicosis, gives rise to cancer, immune suppression, and other "slow" pathological conditions (Etzel, 2002; Maria, 2019).

Grains amongst other commodities, are naturally contaminated with aflatoxigenic moulds. Some strains of these moulds produce aflatoxins during storage (Dovicicova *et al*., 2012; Ezekiel *et al*., 2012; Jianglin *et al*., 2022). Sometimes grains become contaminated with aflatoxins in the field before harvest (Roige *et al*., 2009; Jianglin *et al*., 2022) thereby making it difficult to control the menace of contamination. Field fungi are the moulds that invade the seeds on farms requiring high moisture (20-21 %) (CAST, 2003) for growth, such as *Fusarium* sp, *Cladasporium* sp, and *Alterneria* sp.

Aflatoxins, when produced in grains, could render them, to a greater extent unsafe and unwholesome for human and animal consumption. Even more problematic are grains stored in houses under conditions that favor moulds growth, since most of the storage houses are inadequate and poorly designed, especially at retail shops.

Aflatoxin contamination of feeds has also been interrelated to an increased death rate in farm animals, and it also significantly reduces the quality of grains, which serve as animal feed and also as a commodity for exportation (Aydin *et al*., 2008; Fitalew *et al*., 2023).

Most developing countries in the tropics experience aflatoxin contamination due to high temperatures and relative humidity, poor aeration in stores, insect and rodent damage and the accumulation of aflatoxins in agricultural produce (Hell and Mutegi, 2011; Pleadin *et al*., 2023). Reported incidences of mycotoxin - poisoning are in the sub-saharan Africa, where facilities for monitoring contamination are nonexistent (Bankole *et al*., 2006). Knowledge of aflatoxin contamination has been low especially for human grain consumers due to a low level of education on the existence of aflatoxin in grains for human consumption. Furthermore, there has generally been a low level of awareness and public campaigns to enlighten consumers of grains on the health risks of aflatoxin-contaminated grain consumption. Earlier, Strosnider *et al*. (2006) and Chibundo *et al.* (2021) documented that mycotoxicosis could be reduced through awareness campaigns.

Therefore, the results from this research could serve as a source of awareness of aflatoxin in the study areas. The results will also give an insight into the current aflatoxin levels in grains, thereby creating a review platform for national regulatory levels to monitor the spate of aflatoxins in grains for human consumption.

MATERIALS AND METHODS

Description of the Study Areas

The study areas were North-Central capital cities (Jos, Minna, Makurdi, Lafia, Lokoja, and Ilorin) in Nigeria. It comprises Plaeau state, with its capital city in Jos, and Nassarawa state with with Lafia as the capital. While Markurdi is the capital of Benue State, Lokoja is the capital of Kogi State and Ilorin is the capital of Kwara State. The entire region, according to 2006 census, has a total population of 20,338,257, including the Federal Capital Territory. Agriculture is their major occupation. The six metropolises are the most densely populated within each of the states. Grains such as sorghum, millet, maize, and wheat are the dominant crops consumed directly as flour or in the form of their various products; for example, all the grains could be used as composites for *Kunun-zaki* (a local beverage)*,* bread and, beer production, to mention but a few. In addition, all the grains are vital for feed formulation for layers and broilers within the north-central zone (Figure 1).

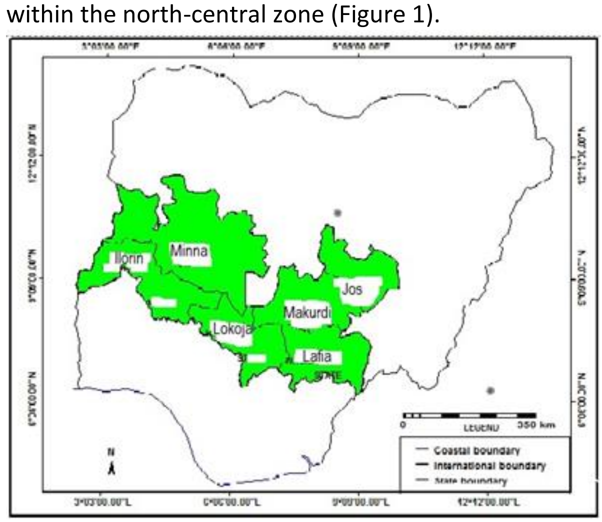

Figure 1: North-Central Capital Cities, Nigeria

Source: Adapted and Modified from Oladimeji *et al.* (2015)

Surveys and Data Collection

A descriptive cross-sectional study on knowledge of moulds and aflatoxin contamination in grains within North-Central capital metropolises was carried out between December, 2022 and November, 2023. Data collection was carried out in the six state capital cities. Interpretation of variables and data on consumers' knowledge of moulds infection and aflatoxin contamination in grains was obtained through the administration of a semi-structured self-administered questionnaire according to Magembe *et al*. (2016) but modified. Data on the level of total aflatoxins were also determined from the samples collected using ELISA.

Sampling

Samples of the grain maize and wheat sold in markets within the metropolises for human consumption were collected from each state capital. Traders who sell the same type of grain at retail and major stores within the metropolis were included in the study as were grain buyers who visited the sellers to buy grains for human consumption. Information as to their knowledge of moulds and aflatoxin was collected from the subjects using a questionnaire for inclusion in this survey. Approximately 200 g of grains were purchased from some vendors, and the samples were placed separately in clean, sterile low-density coded cellophane and transported immediately to the laboratory for analysis. A total of 720 (120 from each capital city) respondents were interviewed on the knowledge of mould infections and aflatoxin contamination in grains sold in different markets within the metropolises.

Human Grain Consumers' and Sellers' Knowledge of Moulds Infection and Aflatoxin Contamination in Grains

Consumer knowledge of mould infection and aflatoxin contamination in grains was achieved through the administration of a self-administered questionnaire. This was also used to collect data on respondents' sociodemographic characteristics (age, gender, education, and marital status). A total of 120 sellers and consumers of grains from major markets were interviewed through the questionnaire spread across each state capital.

The questionnaire was designed to determine knowledge of moulds infection and aflatoxins in grains sold for human consumption using generated statements such as: whether the individual consumes grains, stores grains, knows the right time to buy grains for storage, and knows the causes of spoilage of grains. The questionnaire also included whether the individuals can identify spoiled grains, moulds growth on grains, properly dried grains. The consumers were also asked whether they know about moulds and heard about its ability to produce aflatoxin leading to liver cancer when consumed. Their ability to likely know a measure to be employed for controlling moulds spoilage in stored grains (Table 1). Some samples of the grains: maize and wheat were then bought from the markets and kiosks within the state capitals, and the questionnaire was issued to the sellers and their customers. For those who could not read, the questionnaires were interpreted for them in the language they understood. The statements were measured on the basis of YES and NO.

Determination of total Aflatoxin levels of some grains from North-Central capital cities for human consumption

The total aflatoxin was determined according to RIDASCREEN^{TM} aflatoxin total ELISA Kits manufacturers` instruction as follows: ten grams (10g) of grain samples were ground and aliquot two grams (2g) were weighed out and poured into an extraction bottle with cover. Seventy percent methanol was prepared. Then ten millilitres (10mL) of the 70% methanol was pipetted out and was added to the sample. The mixture was votexed for 10 minutes. Using whatman No.1 filter paper, the sample mixture was filtered and 100µl of the filtrate was diluted using 600µl of distilled water.

The total aflatoxin was detected and quantified by measuring 50µl of enzyme-antibody conjugate using micro pipette and dispense into each well placed on micro well plate. Another aliquot of 50µl of each of the sample (diluted filtrate) and the standard were added into appropriate test wells, then 50µl of antibody was dispensed into each test well. To mix the content, the plate was shaken gently and was incubated at room temperature for 30 minutes. The contents of the wells were discarded and rinsed with distilled water. The process was repeated five times. An absorbent paper was then placed on the flat surface of the test wells and tapped to drain the wash solution.

Then (100µl) of the substrate was pipetted out and dispensed into test well appropriately. Carefully, the plate was shaken and incubated at room temperature for 10 minute. Then aliquot of 100µl of stop solution was dispensed into each test well using pipette and shaken gently.. The optical density was read at 450 nm using imark^{TM} microplate reader. A standard curve of absorbance percentage against log concentration of the standards was plotted and the concentrations of each sample were calculated using an AUTO calculation spreadsheet.

Data Analysis

The mean score of knowledge of mould infection and aflatoxins in grains within the North-Central capital cities was determined using descriptive statistics, while an independent t-test was used to compare mean differences of demographic factors on knowledge of moulds and aflatoxins.

Analysis of variance (ANOVA) was used to determine level of statistical significance difference of group means at ($p \le 0.05$) with less than 0.05 being significant. Data analysis was carried out using SPSS version 25 statistical software.

RESULTS

The determination of knowledge of mould infection and aflatoxins in grains sold within the North-Central capital cities is presented in (Table 1). This study revealed that 32.5%-42.5% of the respondents across the state capitals identified moulds that infect grains. In addition, 29(24.1)-66(55.0%) attributed the spoilage of grains to insufficient drying, while 5(4.20)-44 (36.7%) associated it with a poor storage system. The predominant physical identification of spoilt grains within the study area by the respondents was insect rot 1(0.8)-42(35.0%) and discolouration 15(12.5)-48(40.0%). Both hand feel and biting were the predominant techniques for identifying dried grains 43(35.8) - 60(50.0%) within the study area. Respondents used spoilt grains in various ways, ranging from redrying and mixing with a wholesome batch for human consumption, which had its share of 1(0.8). On one hand, some respondents claimed to throw them away 2(1.7)-42(35.0%), a significant percentage has been selling the spoilt grain to market 4(3.3)-39(32.5%). However, feeding livestock and poultry dominated the respondents' claims, 74(61.7) - 89(74.2%).

Furthermore, results from this work showed that across the study area, there was a very low percentage of 18(15.0)-49(40.8%) of the respondents, with knowledge of aflatoxin production by moulds and with a significant percentage 41(34.2%)-109(90.8%) did not know that aflatoxin causes liver cancer and were thus not aware of the health hazards associated with the consumption of aflatoxin-contaminated grains.

Table 2 presents the explanatory and dependent variables used in the study. On the age category, 1 = greater than 33 years, 0 = less than or equal to 33 years old, while on the educational category, 1 = secondary school and above, 0 = less than secondary school; the marital category indicates 1 = married, 0 = single, divorced or widowed; and the gender category indicates 1 = male, 0 = female.

Table 1. Determination of Knowledge of moulds and Aflatoxin Contamination of Grains Sold in Markets within North-Central Capital Cities for Human Consumption (N=720)

Statements	Response	Jos n (%)	Makurdi n (%)	Lafia n (%)	Minna n (%)	Lokoja n (%)	Ilorin n (%)
Do you consume grains?	Yes	103(85.8)	98 (81.7)	117(97.5)	103(85.8)	87(72.5)	79(65.8)
	No	17 (14.2)	22(18.3)	3 (2.5)	17(14.2)	33(27.5)	41(34.2)
Storage of grains?	Yes	19 (23.3)	28(23.3)	10(8.33)	21(17.5)	16(13.3)	10(8.3)
	No	101(84.2)	92(76.7)	110(91.7	99(82.5)	104(86.7)	110(91.7)
What do you think causes grain spoilage?	Improper fumigation	15 (12,5)	19(15.8)	27 (22.5)	10(8.3)	45(37.5)	50(41.6)
	Poor storage system	44 (36.7)	37(30.8)	31 (25.8)	25(20.8)	10(8.3)	5(4.2)
	Insufficient drying	58 (48.3)	59(49.1)	53 (44.2)	66(55.0)	40(33.3)	29(24.1)
	Heaping on floor	2 (1.7)	10,8()	6 (5.0)	4(3.3)	21(17.5)	2(1.7)
	I don't know	1 (0.8)	13(10.8)	3(2.5)	15(12.5)	4(3.3)	34(28.3)
Can you Identify Spoilt grains?	Yes	107 (89.2)	117(97.5)	105 (87.5)	112(93.3)	75(62.5)	77(64.2)
	No	13 (10.8)	3(2.5)	15 (12.5)	8(6.7)	45(37.5)	43(35.0)
How can you Achieve (4) above?	Smell	19 (15.8)	21(17.5)	22 (18.2)	15(12.5)	25(20.8)	6(5.0)
	Insect rot	20 (16.7)	22(18.3)	35 (29.2)	30(25)	42(35.0)	1(0.8)
	Presence of insects	25 (20.8)	30(25)	18(15.0)	31(25.8)	14(1.7)	31(25.8)
	Discolouration	24 (20)	19(15.8)	15 (12.5)	30(25)	37(30.8)	48(40.0)
	Rot	32(26.7)	28(23.3()	20 (16.6)	14(11.7)	2(1.7)	35(29.2)
What do you use spoilt grains for?	Redry and mix with wholesome batch	0 (0.0)	0(0.0)	1 (0.8)	1(0.8)	0(0.0)	0(0.0)
	Feeding livestock/poultry	79 (65.8)	78(65.0)	83(69.2)	89(74.2)	74(61.7)	82(68.3)
	Throw them away	5 (4.2)	3(2.5)	6 (5.0)	2(1.7)	42(35.0)	14(11.7)
	Sell to market	36 (30.0)	39(32.5)	30 (25.0)	28(23.3)	4(3.3)	24(11.7)
Do you know how to Identify dried grains?	Yes	81 (67.5)	115(95.8)	85 (70.8)	90(75.0)	69(57.5)	49(40.8)
	No	39 (32.5)	5(4.2)	35 (19.2)	30(25.0)	51(42.5)	71(59.2)
What do you use to achieve (7) above?	Hand feel	37 (30.8)	31(25.8)	30 (25.0)	15(12.5)	43(35.8)	21(17.5)
	Biting	40 (33.3)	48(40.0)	33 (27.5)	45(37.5)	27(22.5)	55(45.8)
	Moisture tester	0 (0.00)	0(0.00)	0 (0.0)	0.(0.0)	0(0.0)	00.0)
	Both hand feel & biting	43 (35.8)	41(34.2)	57 (47.5)	60(50.0)	50(41.7)	44(36.7)
Know about moulds?	Yes	70 (58.3)	59(49.2)	77 (64.2)	69(57.5()	65(54.2)	73(60.8)
	No	50 (41.7)	61(50.8)	43 (35.8)	51(42.5)	55(45.8)	47(39.2)
Can you Identify moulds growth on grains?	Yes	51 (42.5)	49(40.8)	50 (41.7)	42(35.0)	39(32.5)	48(40.0)
	No	69 (57.5)	71(59.2)	70(58.3)	78(65.0)	81(67.5)	72(60.0)
Heard about aflatoxin production by moulds?	Yes	41 (34.2)	33(27.5)	45(37.5)	31(25.8)	18(15.0)	49(40.8)
	No	79(85.8)	87(72.5)	75 (62.5)	89(74.2)	102(85.0)	71(59.2)
Know that aflatoxin causes liver cancer?	Yes	28 (23.3)	11(9.2)	15 (12.5)	19(15.8)	19(15.8)	37(30.8)
	No	92 (76.7)	109(90.8)	105 (87.5)	101(84.2)	101(84.2)	83(69.2)
Know measure for controlling moulds in grains?	Yes	77 (64.2)	68(56.7)	79 (65.8)	69(57.5)	38(31.7)	53(44.2)
	No	43 (35.8)	52(43.3)	41 (34.2)	51(42.5)	82(68.3)	67(55.8)

Note: n = total number of samples per state

Table 2. Interpretation of Variables

Awareness	Dependent variable	Categories
	Awareness of moulds infection in grains	1 = Yes, 0 = Otherwise
Age	**Explanatory variables**	**Categories**
	Respondents' age	1 = greater than 33 years 0 = less than or equal to 33 years old
Education	Highest education level reached	1 = secondary school and above 0 = Less than secondary school
Marital status	Marital status of respondents	1 = Married, 0 = Single, divorced or widow
Gender	Gender of respondents	1 = Male, 0 = Female

This study recorded the effects of demographic factors on knowledge of moulds infection and aflatoxin contamination in grains as shown in (Table 3). Age, education, gender and marital status were significant factors in the knowledge of moulds infection and aflatoxin contamination in grains. The mean score of knowledge of moulds infection and aflatoxins in grains by sellers and buyers within the North-Central capital cities of females (79.67±5.20) was significantly higher than males (40.33±5.20) at a p-value of 0.000.

While the mean score was higher among those who attended greater than or equal to secondary school (91.67±7.12), it was lower for those below secondary school (24.50±6.95) at a *p*-value of 0.000. Those whose ages were greater than 33 years had a mean score (84.17±7.28) significantly higher than those less than or equal to 33 years (29.33±7.39) at a *p*-value of 0.000. Those that were married had a higher mean score of knowledge of moulds infection and aflatoxin contamination in grains (82.83±3.19) than others (32.50±2.88) at a *p*-value of 0.000.

The independent *t*-test at a 95% confidence interval (95% CI) on demographic factors on knowledge of moulds and aflatoxins in grains is shown in (Table 4). The *t*-test analysis indicates the relationship between gender, education, age and marital status compared to knowledge of moulds infection and aflatoxins in grains. The mean difference between sexes is 56.75. This could mean that the female respondents were 56.75 times more likely to have better knowledge of moulds infection and aflatoxin contamination than the male respondents at a t-test value (6.669). Similarly, the mean difference of 60.00 could mean that respondents with an age greater than 33 years could be 60.00 times more likely to have better knowledge of moulds infection and aflatoxin contamination than those who had an age less than 33 years. It is obvious that older individuals could be more likely to judge and sense risks better than young ones below or equal to 33 years of age at the *t*-test (9.836).

The t-test of 7.554 revealed that respondents who were married could be 57.67 more likely to have better knowledge of moulds infection and aflatoxin contamination than those who were single, divorced, and widowed (others). The findings from this research present significant differences between men and women with respect to the knowledge of mould infection and aflatoxin contamination in grains. A mean difference of 58.08 shows that respondents with less than secondary level education could be more likely to have 58.08 times lesser knowledge of mould infection and aflatoxins contamination in grains than those in greater than secondary school level education, at a *t*-test value (5.634).

The mean total aflatoxin (µg/kg) levels in maize and wheat sold for human consumption in markets within North-Central state capital cities is presented in Table 5. All the grain samples collected contain different aflatoxin levels. Maize samples from Makurdi had the highest aflatoxins level (3.28±1.49) and Ilorin had the least (1.98±0.60). Similarly, wheat samples from Minna had the highest aflatoxin level (2.82±1.17) and samples from Makurdi recorded the lowest aflatoxin level (2.16±1.25). However, it is not alarming. Only 11.7% of the grain samples collected from the capital cities exceeded the 4 ug/kg European limit of aflatoxins.

Table 3. Mean Score of Knowledge on Moulds Infection and Aflatoxin Contamination of Grains Sold in Major Markets, North-Central Capital Cities

Variable	Mean Score	*P*-value
Age		
≤33	29.33±7.39	0.000*
>33	84.17±7.28	
Sex		
Female	79.67±5.20	0.000**
Male	40.33±5.20	
Marital Status		
Others	32.50±2.88	0.000*
Married	82.83±3.19	
Educational Status		
Less than Secondary	24.50±6.95	0.000*
Sec. School and above	91.67±7.12	

Values with asterisks indicate statistical significance at *p*-value (<0.05)

Table 4: Independent t-test on Demographic Factors Knowledge of Moulds and Aflatoxin Contamination of Grains Sold in Major Markets, North-Central Capital Cities

Variable	Mean difference	t-value	95% Confidence Level	
			Lower	Upper
Sex	56.75	6.669	38.02	75.48
Age	60.00	9.836	46.57	73.43
Marital status	57.67	7.554	40.86	74.47
Educational status	58.08	5.634	35.39	80.77

Table 5. Mean± SD Total Aflatoxin Levels (µk/kg) of Grains sold in Major Markets for Human Consumption within North-Central Capital Cities

Grain	State Capitals					
	Jos	Lafiya	Minna	Lokoja	Ilorin	Markudi
Wheat	2.3±0.96[a]	2.74±0.67[a]	2.82±1.17[a]	2.62±0.63[a]	2.56±1.09[a]	2.16±1.25[a]
Maize	2.86±0.36[a]	2.72±1.27[a]	2.26±0.44[a]	2.78±1.11[a]	1.98±0.60[a]	3.28±1.49[a]

Values are presented as mean ± SD, and values with the same superscript within the same row show no significant difference (p > 0.05)

DISCUSSION

The use of spoiled grains in this research could have public health implications. The contaminated grains are being consumed by animals and humans within the study area. This could result in a high risk of aflatoxicosis. This could also trigger adverse effects on livestock production and international trade. It has been reported that aflatoxin B1 in animals, when consumed, is converted to another toxic form called aflatoxin M1 (Strosnider *et al*., 2006; Maria, 2019; Álvarez-Días *et al*., 2022). From this study, female respondents showed greater awareness of moulds infection and aflatoxin contamination because they are responsible for most of the retailing of grains and nuts activities within the region. The outcome of this work can be seen here: educational level, knowledge, and age could be key players in curtailling the problems of moulds infection and aflatoxin contamination in grains. In a similar study conducted by Patchimaporn *et al.* (2018) reported that more educated households were more knowledgeable about aflatoxins than the less educated. This conforms to the findings of this study. People with higher levels of education are likely to be more reasonable, better enlightened, and likely to have options due to their level of intelligence.

The study reports that 18 (15.0%) – 49 (40.8%) of the respondents knew about aflatoxin production by moulds and a significant percentage of 60 (50.2%) – 102 (85.0%) did not know about aflatoxin production by moulds. This result is lower than Ifeoluwa *et al.* (2017) who reported (98%) of respondents were not aware of mycotoxins contamination. Earlier, Magambe *et al.* (2016) reported (97%) of respondents were not aware of mould infections in stored maize and groundnuts. Similarly, Chibundo *et al.* (2021) also reported low awareness of mycotoxin in their study among household consumers of cereals, nuts, and legumes in North-Central Nigeria.

The mean score of knowledge of moulds infection and aflatoxin contamination was higher in females (79.67±5.20) than in males (40.33±5.20) in this study. This is similar to the work of Magambe *et al.* (2016) who reported the mean score of males (1.57±13.7) and females (1.72±0.450). The high difference in mean score could be due to the difference in sample size between the two studies, as seen in table 3. Awareness of aflatoxin was higher in farmers with higher education than those with lower education, as reported by Ayo *et al.* (2018). This is similar to the reports of this study; however, this study was carried out in the capital cities of the North-Central States, Nigeria. Most educated respondents reside in the cities, hence the high score.

Other authors have reported different concentrations of aflatoxins in grains. Shittu *et al*. (2021) reported a high concentration of aflatoxin (11.04 µg/kg) in millet and a low concentration in sorghum (1.07 µg/kg). Keta *et al*. (2019) also revealed that maize grains in Argungu markets had the highest aflatoxin contents of 187.90±14.83µg/kg, while the lowest aflatoxin content of 1.80 ± 7.84 µg/kg was obtained in maize grains from Aliero silos. The mean concentrations of total aflatoxin in this study are higher than the 0.62µg/kg reported in millet from Katsina state by Batagarawa *et al*. (2015) and Ezekiel (2014), who reported a range of 0.08 - 1.40 µg/kg for the same type of grain.

Maize has the highest mean total aflatoxin of (3.28±1.49 µg/kg)) from Makurdi and the least from Ilorin (1.98±0.60 µg/kg). There was no significant difference between the means of total aflatoxins in this study.

The work of the authors, Atehnkeng *et al*. (2008) had earlier reported 30.9 - 507.9 µg/kg for maize from 11 districts across three agro-ecological zones of Nigeria, which is higher than the range obtained from this study. The findings from Kamala *et al*. (2016) reported a 45% prevalence of aflatoxins in maize samples from various agroecological zones of Tanzania, with levels that ranged from 0.1-269 µg kg^{-1}. A report by Burger *et al*. (2013) has earlier explained these variations, as grains could be contaminated due to improper post-harvest handling and/or storage, in addition to the inability to control environmental factors such as high temperature, high relative humidity, and storage conditions. These factors could promote the growth of aflatoxigenic moulds and aflatoxin production when conditions are favourable (Jianglin *et al*., 2022). The low values of aflatoxin obtained in this work could be because the samples were collected from open markets where every seller will probably have to sort the grains before displaying them for sale to attract customers, hence the low determined total aflatoxin values.

Due to the adverse health consequences of aflatoxins (IARC, 2002; Ayo *et al*., 2018), there is a need for prevention, especially for high-risk populations.

Hence, the present study advocates proactive measures geared towards raising cognizance of mould infection and aflatoxin contamination of grains. In addition, the outcome of this work could be harnessed to form the basis for taking a preventive approach, especially in the implementation of already existing national food policy laws that will help to enlighten the region through public campaigns on the impact of aflatoxins on human and animal health.

CONCLUSION

A survey of knowledge of moulds and aflatoxin contamination in grains sold for human consumption within the six North-Central capital cities of Nigeria was determined. This study revealed that 32.5%-42.5% of the respondents across the study areas identified moulds that infect grains. More so, a significant percentage 34.2%-90.8% of the respondents across the states did not know that aflatoxin causes liver cancer. The grain samples analyzed were found to be contaminated with varying amounts of total aflatoxins. The aflatoxin contamination levels show no statistically significant differences ($p > 0.05$). The study recorded that 11.7% of the samples exceeded 4.0 µg/kg of the European limit of aflatoxin. More so, all the grains were within the 10 µg/kg permissible limit recommended by NAFDAC. It is therefore imperative that similar research on mould infection and aflatoxin contamination of grain surveillance, such as the one presented in this study, form the basis for taking different preventive approaches, through public campaigns on the impact of aflatoxins on human and animal health.

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Conflict of Interests

The authors declare that there is no conflict of interest.

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