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Research article

Assessment of Aflatoxin B_1 Potential Non-Carcinogenic and Hepatocellular Carcinoma Risk Associated with consumption of some Staple Foods across Northeastern Nigeria

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Abstract
Aflatoxin B_1 (AFB_1) remains one of the most potent and widely distributed mycotoxins found in global food systems, especially within warm, humid regions where fungal growth is favourable. It is a toxic secondary metabolite predominantly produced by *Aspergillus flavus*, a fungus known to contaminate a broad range of agricultural commodities including maize, rice, groundnuts, cereals and other staple foods. This study evaluated Aflatoxin B_1 (AFB_1) contamination, dietary exposure, margin of exposure (MOE), and hepatocellular carcinoma (HCC) risk associated with consumption of contaminated maize, millet, cowpea, and peanut across selected areas of Borno and Yobe States, Northeastern Nigeria. Monthly sampling was conducted between November 2024 and February 2025 across major markets, followed by HPLC quantification of AFB_1 and subsequent risk evaluation. Results showed strong seasonal variation, with January exhibiting the highest contamination levels in peanuts with concentration of (69.12 µg/kg) and followed by maize with 27.26 µg/kg. Estimated Daily Intake (EDI) values for both adults and children exceeded the provisional maximum tolerable daily intake (PMTDI) threshold during peak months, while MOE values consistently fell far below the safety benchmark of 10,000, indicating significant public health concern. Potential liver cancer burden estimations also revealed heightened risk, particularly among children in Damaturu and Gashua were found to be the hotspots. Overall, the findings of this study demonstrate significant potential AFB_1 related health risks in northeastern Nigeria, underscoring the urgent need for improving post-harvest handling, storage interventions, stronger regulatory oversight, and public-health risk mitigation strategies, therefore, there is an urgent need for regulatory enforcement on AFB1 limits within food supply chains and strengthen post-harvest drying and storage in Nigeria.

Keywords: Aflatoxin B_1, Margin of Exposure, Hepatocellular carcinoma, Food safety,

INTRODUCTION

Aflatoxin B_1 (AFB_1) is one of the most potent and widely distributed mycotoxins associated with global food systems, especially within warm, humid regions where fungal growth is favourable. It is a toxic secondary metabolite predominantly produced by *Aspergillus flavus*, a fungus contaminating a broad range of agricultural commodities including maize, rice, groundnuts, cereals and other staple foods (Mardani *et al.*, 2011; Hamid *et al.*, 2013). Over the years, extensive toxicological and epidemiological studies have established AFB_1 as a major public health threat because of its strong genotoxic, mutagenic and carcinogenic properties in both humans and animals (Berg *et al*., 2011; Corcuera *et al*., 2015; Hernandez- Vargas *et al*., 2015; Smith; *et al*., 2015Marrone *et al*., 2016).

The International Agency for Research on Cancer (IARC) formally classifies AFB_1 as a Group 1 carcinogen, clear evidence linking to chronic dietary exposure to the development of hepatocellular carcinoma (HCC) (IARC, 2002).

The biological mechanism underlying this carcinogenicity involves the metabolic conversion of AFB_1 by cytochrome P450 enzymes into a highly reactive epoxide. This intermediate binds covalently to DNA in the liver cells, forming characteristic lesions such as the AFB_1 - N7- Guanine adduct (Croy *et al*., 1978). These adducts destabilize DNA structure, create strand breaks and promote mutations that may trigger liver tumour formation.

Global regulatory agencies have set maximum allowable limits for AFB_1 in food to reduce exposure risk. The European Commission, through Regulation EC No. 1881/2006, restricts AFB_1 levels in cereals and peanuts for direct human consumption to ≤ 2 ng/g. The National Agency for Food and Drug Administration and Control (NAFDAC) has adopted the ≤ 2 ng/g set by European Commission. In contrast, the United States Food and Drug Administration (FDA) permits up to 20 ng/g in maize and peanut products (FDA, 2017). However, despite these regulatory frameworks, AFB_1 contamination continues to pose serious challenges, particularly in developing regions with limited monitoring capacity and high reliance on susceptible staple crops.

Climate change has further intensified global concern regarding aflatoxin contamination. Rising temperatures and increased atmospheric CO_2 are projected to elevate the growth and toxin producing potential of *Aspergillus flavus*. Battilani *et al*. (2016) reported that an increase in temperature ranges between 2°C to 5°C could significantly heighten AFB_1 contamination risk in European maize. Medina *et al*. (2014) also demonstrated that warmer temperatures and elevated CO_2 concentrations stimulate aflatoxin synthesis, suggesting that regions with warm climates such as tropical countries, including Nigeria may face escalating contamination episodes.

Traditional exposure assessments in Africa have relied on direct contamination measurements; however, integrating toxicological modeling through the Margin of Exposure (MOE) and Joint FAO/WHO Expert Committee on Food Additives (JECFA) cancer potency frameworks provides a more comprehensive risk characterization. The MOE approach, recommended by EFSA (2005), compares a benchmark dose lower confidence limit ($BMDL_{10}$ = 400 ng/kg-bw/day) with estimated exposure. Values below 10,000 indicate a level of health concern, especially for genotoxic carcinogens such as AFB_1 . In Nigeria, maize, millet, cowpea and peanuts are the major dietary of millions of people, in which AFB_1 contamination presents a persistent food safety and public health challenge. Favorable environmental conditions promote optimal fungal growth, while postharvest storage systems remain largely inadequate in many developing countries. Consequently, exposure to AFB_1 continues to pose a significant liver cancer risk, especially in communities with high prevalence of hepatitis B virus (HBV) prevalence.

The present study was designed to: (i) quantify AFB_1 contamination levels across major food types across various locations of northeastern Nigeria; (ii) estimate the daily human exposure and compute the corresponding MOE; (iii) assess the liver cancer burden attributable to AFB_1 exposure using Joint FAO/WHO Export Committee on Food Additives (JECFA's) HCC potency factors; and (iv) examine the influence of HBV prevalence 15%) on cancer risk through sensitivity analysis. By integrating chemical exposure data with health risk modeling, this study provides an evidence based framework for prioritizing aflatoxin control and public health interventions in Nigeria.

MATERIALS AND METHODS

Study Area and Study Population

The study was conducted in some local government areas of Borno (Maiduguri Metropolitan Council, Jere and Konduga) and Yobe states (Damaturu, Potiskum and Gashua) situated in northeastern Nigeria. The majority of the population in the communities depends on large scale cultivation of staples crops including groundnuts, cowpea, maize, millet sorghum, etc.) for their income. Borno State is located in the northeast corner of Nigeria, sharing borders with Chad to the northeast and Cameroon to the east, while Yobe State is situated to the west of Borno State, with its northern border adjacent to Niger Republic (Akinpelu, 2012). These states are characterized by semi-arid regions and savannahs, and are significant agricultural hubs in Nigeria. with mycotoxin contamination that poses significant risks to food safety and human health (Oyelami *et al.*, 2017).

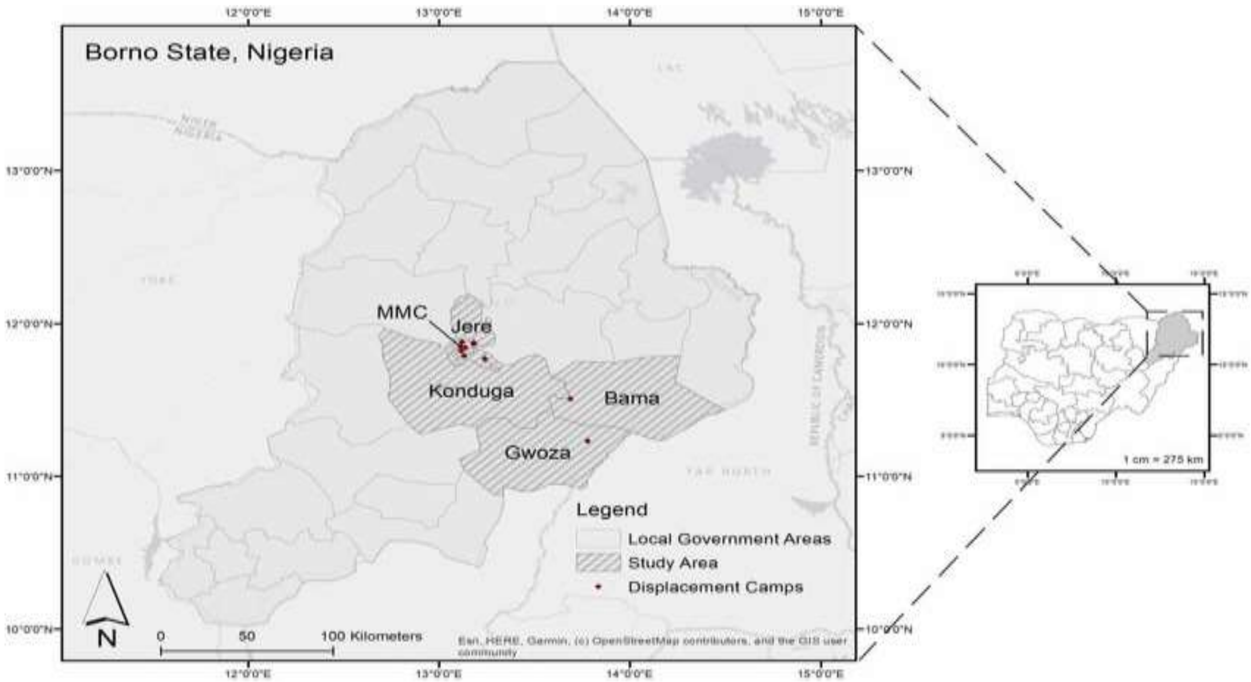

Figure 1. A map showing sampling location in Borno state study area (Zanna *et al*., 2024)

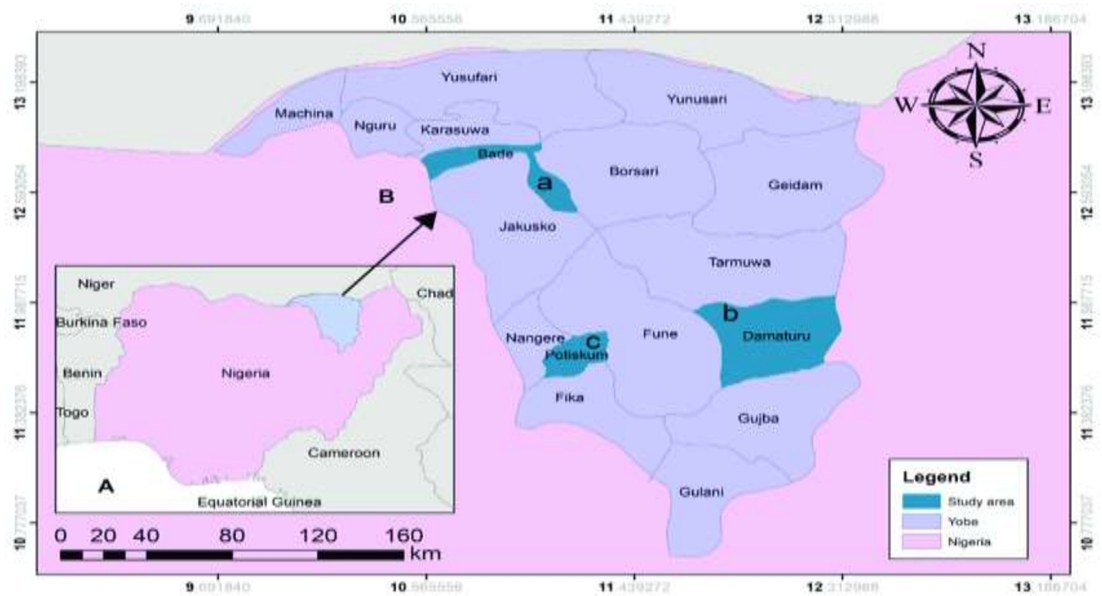

Figure 2. A map showing sampling location in Yobe state study area

This study employed a structured and scientifically robust methodology for assessing mycotoxin contamination in maize, millet, cowpea, and peanut collected across different marketplaces in Borno and Yobe State between November 2024 and February 2025. A cross-sectional sampling design was used to capture spatial variability in contamination and consumer exposure. One-kilogram samples of each crop type were collected monthly, placed in sterile polyethylene bags, and stored under cool, dry conditions to prevent post-collection fungal growth. Sampling sites were purposively chosen to represent major retail points, while individual vendors were selected randomly to ensure unbiased representation. Composite dry weight samples were produced by homogenizing grains pooled from three vendors (Kortei *et al*., 2020a).

Sample preparation

The collected samples were cleaned to remove debris, damaged grains, and foreign materials, and then ground into fine powder using a sterile electric blender. The powdered samples were sieved (≤500 µm) for uniform particle size and stored in airtight containers at 4°C until extraction. For mycotoxin extraction, 5 g of homogenized sample was weighed into a 50 mL centrifuge tube and extracted with 25 mL of a mixture of acetonitrile: water (84:16 v/v). The mixture was shaken for 60 minutes and centrifuged at 4000 rpm for 10 minutes. The supernatant was filtered through Whatman No. 1 filter paper and passed through immunoaffinity columns specific for each mycotoxin prior to HPLC analysis (Ezekiel *et al*. (2012).

Analysis of Sample Using HPLC

Quantification of aflatoxins was performed using HPLC (Agilent 1220 LC (Liquid Chromatograph) with a fluorescence detector (Diode Array Detector) and a reverse phase C18 column. Calibration curves were prepared from certified standards, and detection limits were based on signal to noise ratios of 3:1 and 10:1. Mycotoxins were identified using retention times (15 minutes run time), flow rate 1ml/mins, 20 µl injection volume and spectral characteristics, and concentrations were expressed in µg/kg (Kolosova and Stroka 2011).

Health Risk Assessment

Health risk assessment was carried out to evaluate the potential human exposure to mycotoxins through consumption of contaminated food crops. The assessment included the estimation of Estimated Daily Intake (EDI), Margin of Exposure (MOE), and Cancer Risk (Burden Estimation) for adult and child populations.

Estimated Daily Intake (EDI)

The EDI (ng/kg body weight/day) for each mycotoxin was calculated using the equation adapted from (Udovicki *et al*., 2021).

$$\text{EDI} = \frac{(CxD)}{BW}$$

Where:

C = Mean concentration of mycotoxin in the food (µg/kg),D = Daily consumption rate of the food (kg/day), BW = Average body weight (kg) of consumer (60 kg for adults, 25 kg for children) adapted from Akinpelu *et al.*, 2015).Toxicological reference: BMDL10 = 400 ng/kg-bw/day (MOE metric).Daily consumption Adults: Maize 0.20, Millet 0.20, Cowpea 0.10, Peanut 0.05 kg/day; BW = 60 kg.Children (10–12 yrs): Maize 0.15, Millet 0.15, Cowpea 0.08, Peanut 0.03 kg/day; BW = 25 kg based on the (NBS/world Bank, 2016)..

Margin of Exposure (MOE) The MOE was calculated to evaluate the possible health concern associated with mycotoxin exposure using:

$$\text{MOE} = \frac{BMDL10}{EDI}$$

Where BMDL_{10} represents the benchmark dose lower confidence limit for a 10% cancer risk (400 ng/kg bw/day for AFB_1). An MOE value below 10,000 indicates a potential health concern for exposed populations.

Cancer Burden Estimation

The cancer risk associated with dietary exposure to aflatoxins was estimated using the formula: Cancer Risk = EDI × Potency Factor Where the potency factor for aflatoxin B_1 is 0.01 cancer cases per 100,000 population per ng/kg bw/day (for HBsAg-negative individuals) as adopted by (Garba *et al*., 2021). The cancer burden (number of cases per 100,000 persons per year) was then derived by multiplying the cancer risk by the estimated exposed population.

Data Analysis

The data was analyzed using one way Analysis of variance (Anova) and multiple comparison test Duncan test.

RESULTS: `

Mean AFB1 Concentration in staple crops

Mean AFB1 concentrations varied widely across the monthly samples (Nov 2024–Feb 2025). In November, maize showed means ranging from a maximum of 1.19 µg/kg in Konduga to maximum of 2.26 µg/kg in Jere and MMC, while the concentration range of (0.05 to0.74 µg/kg in millet was found very low). The concentrations in peanut ranged from 0.97 to2.71 µg/kg (Table 1).

In December, the concentration in maize increased dramatically at Konduga to (25.26 μg/kg) and 12.15 μg/kg recorded in MMC (Table 2). January recorded the highest contamination in peanut with the concentration of 69.12 μg/kg recorded in maize collected in Damaturu (Table 3). February, the concentration dropped significantly, with maize recorded between 0 to 3.8 μg/kg (Table 4). This pattern shows sharp seasonal contamination spikes, especially in January.

Estimated Daily Intake (EDI)
EDI values followed similar concentration trend with AFB1 concentration recorded in staple crops. In November, adult EDI values of maize ranged from a minimum of 4.0–7.5 ng/kg-bw/day, while children recorded much higher values (7.1–13.6 ng/kg-bw/day). In December, maize EDI values peaked at 151.6 ng/kg-bw/day for Konduga children and 84.2 for adults. January produced the highest EDI values with Damaturu children reaches 163.6, while adults recorded an average of 90.9 ng/kg-bw/day. February EDI values declined markedly for all crops, with adult maize EDI values ranging from 0 to12.7 ng/kg-bw/day, while peanut and millet EDI values also spiked in January but stabilized by February (Table 1, 2, 3 and 4).

Margin of Exposure (MOE)
MOE (400/EDI) demonstrated high potential cancer risk in the months with elevated AFB1 (November). In November, maize MOE for adults ranged between 53–100.8, while children recorded between 29.5–56.0 MOE values. December showed critically low MOEs, such as 2.6 for Konduga children and 4.8 for adults due to extreme maize contamination. The January spike caused further MOE depression, with several values falling below 10, especially in maize and peanut. February exhibited recovery, with maize MOE rising above 25–126 for adults and 17–70 for children. ((Table 1, 2, 3 and 4).

Liver Cancer Burden
Liver cancer burden values reflected potential chronic exposure intensity. For maize, adult burden ranged from 0.646 (Jere) to 1.4869 per 100,000 (Konduga). Children showed even higher burdens (0.9696–2.2303 per 100,000). Millet burdens remained moderate (0.55–1.30 per 100,000 for adults and ranges between; 0.83–1.96 per 100,000 for children). Cowpea remained consistently low (<0.36) while peanut burdens were moderate to high, especially in Damaturu children (1.2669 per 100,000). The burden pattern confirms maize and peanuts as major contributors (Table 5).

Table 1. Mean Concentration of AFB I, EDI and MOE of some Food Crops from North East, Nigeria, November, 2024

Food crop		Borno State						Yobe State					
	Scenario	Jere		Konduga		MMC		Damaturu		Gashua		Potiskum	
		Mean	EDI/(MOE)	Mean	EDI/(MOE)	Mean	EDI/(MOE)	Mean	EDI/(MOE)	Mean	EDI/(MOE)	Mean	EDI/(MOE)
Maize	Adult	2.26	7.5 (53.1)	1.19	4.0(100.8)	2.15	7.2(55.8)	1.3	4.3(92.3)	1.41	4.7(85.1)	2.01	6.7(59.7)
	Children	2.26	13.6(29.5)	1.19	7.1(56.0)	2.15	12.9(31.0)	1.3	7.8(51.3)	1.41	8.5(47.2)	2.01	12.1(33.2)
Millet	Adult	0.09	0.3(1333.3)	0.74	2.5(162.2)	0.08	0.3(1500.0)	0.05	0.2(2400.0)	0.27	0.9(444.4)	0.39	1.3(307.7)
	Children	0.09	0.5(740.7)	0.74	4.4(90.1)	0.08	0.5(833.3)	0.05	0.3(1333.3)	0.27	1.6(246.9)	0.39	2.3(170.9)
Cowpea	Adult	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Children	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Peanut	Adult	1.9	1.6(252.6)	2.71	2.3(177.1)	0.97	0.8(494.8)	1.16	1.0(413.8)	1.92	1.6(250.0)	1.59	1.3(301.9)
	Children	1.9	2.3(175.4)	2.71	3.3(123.0)	0.97	1.2(343.6)	1.16	1.4(287.4)	1.92	2.3(173.6)	1.59	1.9(209.6)

Mean concentration in (μg/kg), EDI ((ng/kg-bw/day), MOE (=400/EDI)

Table 2. Mean Concentration of AFB I, EDI and MOE of some Food Crops from North East, Nigeria, December, 2024

Food crop		Borno State						Yobe State					
	Scenario	Jere		Konduga		MMC		Damaturu		Gashua		Potiskum	
		Mean	EDI/(MOE)	Mean	EDI/(MOE)	Mean	EDI/(MOE)	Mean	EDI/(MOE)	Mean	EDI/(MOE)	Mean	EDI/(MOE)
Maize	Adult	1.57	5.2(76.4)	25.26	84.2(4.8)	12.15	40.5(9.9)	8.97	29.9(13.4)	6.72	22.4(17.9)	4.68	15.6(25.6)
	Children	1.57	9.4(42.5)	25.26	151.6(2.6)	12.15	72.9(5.5)	8.97	53.8(7.4)	6.72	40.3(9.9)	4.68	28.1(14.2)
Millet	Adult	0.0	0.0	0.0	0.0	13.3	44.3(9.0)	4.68	15.6(25.6)	0.65	2.2(184.6)	6.27	20.9(19.1)
	Children	0.0	0.0	0.0	0.0	13.3	79.8(5.0)	4.68	28.1(14.2)	0.65	3.9(102.6)	6.27	37.6(10.6)
Cowpea	Adult	0.0	0.0	6.0	10.0(40.0)	0.0	0.0	5.81	9.7(41.3)	0.0	0.0	1.35	2.3(177.8)
	Children	0.0	0.0	6.0	19.2(20.8)	0.0	0.0	5.81	18.6(21.5)	0.0	0.0	1.35	4.3(92.6)
Peanut	Adult	8.4	7.0(57.1)	6.1	5.1(78.7)	10.2	8.5(47.1)	8.42	7.0(57.0)	13.3	11.1(36.1)	3.17	2.6(151.4)
	Children	8.4	10.1(39.7)	6.1	7.3(54.6)	10.2	12.2(32.7)	8.42	10.1(39.6)	13.3	16.0(25.1)	3.17	3.8(105.2)

Mean concentration in (μg/kg), EDI ((ng/kg-bw/day), MOE (=400/EDI)

Table 3. Mean Concentration of AFB I, EDI and MOE of some Food Crops from North East, Nigeria, January, 2025

Food crop		Borno State						Yobe State					
	Scenario	Jere		Konduga		MMC		Damaturu		Gashua		Potiskum	
		Mean	EDI/(MOE)	Mean	EDI/(MOE)	Mean	EDI/(MOE)	Mean	EDI/(MOE)	Mean	EDI/(MOE)	Mean	EDI/(MOE)
Maize	Adult	19.57	65.2(6.1)	18.35	61.2(6.5)	16.15	53.8(7.4)	27.26	90.9(4.4)	10.5	35.0(11.4)	11.02	36.7(10.9)
	Children	19.57	117.4(3.4)	18.35	110.1(3.6)	16.15	96.9(4.1)	27.26	163.6(2.4)	10.5	63.0(6.3)	11.02	66.1(6.0)
Millet	Adult	11.94	39.8(10.1)	18.47	61.6(6.5)	11.92	39.7(10.1)	19.69	65.6(6.1)	11.65	38.8(10.3)	7.32	24.4(16.4)
	Children	11.94	71.6(5.6)	18.47	110.8(3.6)	11.92	71.5(5.6)	19.69	118.1(3.4)	11.65	69.9(5.7)	7.32	43.9(9.1)
Cowpea	Adult	19.5	32.5(12.3)	6.72	11.2(35.7)	10.98	18.3(21.9)	5.25	8.8(45.7)	15.52	25.9()15.5	12.99	21.7(18.5)
	Children	19.5	62.4(6.4)	6.72	21.5(18.6)	10.98	35.1(11.4)	5.25	16.8(23.8)	15.52	49.7(8.1)	12.99	41.6(9.6)
Peanut	Adult	14.28	11.9(33.6)	47.64	39.7(10.1)	25.5	21.3(18.8)	69.12	57.6(6.9)	23.15	19.3(20.7)	57.85	48.2(8.3)
	Children	14.28	17.1(23.3)	47.64	57.2(7.0)	25.5	30.6(13.1)	69.12	82.9(4.8)	23.15	27.8(14.4)	57.85	69.4(5.8)

Mean concentration in **(**μg/kg), EDI ((ng/kg-bw/day), MOE (=400/EDI)

Table 4. Mean Concentration of AFB I, EDI and MOE of some Food Crops from North East, Nigeria, February, 2025

Food crop		Borno State						Yobe State					
	Scenario	Jere		Konduga		MMC		Damaturu		Gashua		Potiskum	
		Mean	EDI/(MOE)	Mean	EDI/(MOE)	Mean	EDI/(MOE)	Mean	EDI/(MOE)	Mean	EDI/(MOE)	Mean	EDI/(MOE)
Maize	Adult	0.00	0.00	3.2	3.2(126.3)	2.66	8.9(45.1)	3.8	12.7(31.6)	2.25	7.5(53.3)	2.6	8.7(46.2)
	Children	0.00	0.00	3.2	5.7(70.2)	2.66	16.0(25.1)	3.8	22.8(17.5)	2.25	13.5(29.6)	2.6	15.6(25.6)
Millet	Adult	5.04	16.8(23.8)	21.3	21.3(18.8)	10.45	34.8(11.5)	15.88	52.9(7.6)	7.46	24.9(16.1)	10.45	34.8(11.5)
	Children	5.04	30.2(13.2)	38.3	38.3(10.4)	10.45	62.7(6.4)	15.88	95.3(4.2)	7.46	44.8(8.1)	10.45	62.7(6.4)
Cowpea	Adult	0.00	0.00	0.65	1.1(369.2)	4.68	7.8(51.3)	8.97	15.0(26.8)	6.72	11.2(35.7)	5.32	8.9(45.1)
	Children	0.00	0.00	0.65	2.1(192.3)	4.68	15.0(26.7)	8.97	28.7(13.9)	6.72	21.5(18.6)	5.32	17.0(23.5)
Peanut	Adult	15.35	12.8(31.3)	10.02	8.4(47.9)	16.57	13.8(29.0)	25.25	21.0(19.0)	12.15	10.1(39.5)	11.5	9.6(41.7)
	Children	15.35	18.4(21.7)	10.02	12.0(33.3)	16.57	19.9(20.1)	25.25	30.3(13.2)	12.15	14.6(27.4)	11.5	13.8(29.0)

Mean concentration in (μg/kg), EDI ((ng/kg-bw/day), MOE (=400/EDI)

Table 5. Liver Cancer Burden for Adult and Children in North Eastern Nigeria

		Borno		Yobe			
Food crop	Scenario	Jere	MMC	Konduga	Damaturu	Gashua	Potiskum
Maize	Adult	0.6464	1.0761	1.4869	1.3432	0.6786	0.6601
Maize	Children	0.9696	1.6141	2.2303	2.0148	1.0179	0.6601
Millet	Adult	0.5548	1.1619	0.8317	1.3098	0.651	0.794
Millet	Children	0.8322	1.7428	1.2475	1.9646	0.9765	1.191
Cowpea	Adult	0.2844	0.2545	0.2173	0.3255	0.3614	0.3195
Cowpea	Children	0.4266	0.3817	0.3259	0.4882	0.5421	0.4792
Peanut	Adult	0.3244	0.4326	0.5401	0.8446	0.4105	0.6021
Peanut	Children	0.4866	0.6489	0.8101	1.2669	0.6157	0.9032

DISCUSSION

The results of this study demonstrate that Aflatoxin B_1 contamination in maize, millet, cowpea, and peanuts across northeastern Nigeria remains a substantial food safety challenge, with clear seasonal variations, elevated exposure estimates, and critically low MOE values. The sharp peak recorded in January when the concentration in maize reached 27.26 μg/kg and peanuts with 69.12 μg/kg highlights the influence of dry-season storage conditions that favour Aspergillus proliferation. Similar seasonal surges have been documented across tropical regions, underscoring the role of post-harvest handling and climatic factors in aflatoxin dynamics (Badmos, 2025). The AFB_1 concentrations observed in this study fall within, but often exceed, the values reported across sub-Saharan Africa. For example, Kolawole *et al*. (2020) reported extremely high maize contamination in Ondo State (265 μg/kg), showing that Nigerian cereals remain highly vulnerable to fungal colonization. Comparable study in Ghana also found high maize contamination with aflatoxins B_1 (234 μg/kg) (Kortei, *et al*., 2022). Similarly, Leong *et al.*, (2011) found a ranged between 0.40-222ng/g in Malaysian peanuts. However, Trung *et al*., (2008) reported a contrasting result in Vietnan with a concentration range between (2.1-31.1 ng/kg). Some extreme cases exceed even these levels, such as the 6000 ng/g peanut contamination reported in East Java (Goto *et al*., 2000), which was associated with fatal aflatoxicosis outbreaks similar to the Kenya event of 2004 (Lewis *et al.*, 2005). Moreover, the contamination in northeastern Nigeria did not reach these catastrophic levels, but several maize and peanut samples in December–January surpassed global regulatory limits, especially the EU threshold of 2 μg/kg for cereals.

Estimated Daily Intake (EDI) and MOE

The EDI values calculated in this study mirror the contamination trend. Children consistently exhibited higher exposure levels due to lower body weight. The December–January peak produced EDI values as high as 84.2 ng/kg bw/day in adults and 163.6 ng/kg bw/day in children. These values are significantly above international benchmarks and parallel reports from Asia and South America. For instance, Monger *et al.* (2024) reported EDI values of 0.98–5.34 ng/kg bw/day for aflatoxin exposure through chili products in Bhutan far lower than those observed in this study. Similarly, the EDI values estimates published by Mehdi *et al*. (2019) for Iranian wheat-based products represent (0.26 mg/kg-day in adults and 0.04 mg/kg-day in children) and Alim *et al*. (2018) reported that the Pakistani wheat flour (1.20 ng/kg bw/day) also fall below the exposure burdens recorded in this study. These comparisons highlight Nigeria's elevated dietary risk profile due to reliance on highly susceptible staples and weak food safety controls measures.

The Margin of Exposure (MOE) values further emphasize public health concerns. The present study recorded MOE values of 2.6 in heavily contaminated maize consumed by children far below the safety reference value of 10,000. Comparable studies also report low MOEs, but typically not as severe. Monger *et al*. (2024) in Bhutan reported MOEs ranging between 74.9–408.1, while Hoteit *et al*. (2024) documented MOEs of 827.9 in rice and 4868.5 in bulgur. Even these lower-risk food systems still signal unacceptable exposure. In Nigeria, Badmus *et al*. (2025) found MOEs associated with maize 2.79. Despite being considered high-risk, these values remain lower than the burdens documented in the northeastern Nigerian population.

CONCLUSION

This study demonstrates that Aflatoxin B_1 contamination of staple foods in northeastern Nigeria poses a potential significant chronic health risk, particularly through maize and millet consumption. AFB1 contamination showed significant seasonal and spatial variability across northeastern Nigeria. January consistently presented the highest contamination, exposure, and cancer risk estimates. Damaturu and Gashua were identified as contamination hotspots, while MMC recorded the lowest values. Maize and peanuts emerged as the leading contributors to dietary aflatoxin risk, with children bearing the highest vulnerability. MOE values across several months fell below critical thresholds, indicating public health concern. Liver cancer burden calculations reaffirm the severity of chronic exposure. Therefore, there is an urgent need for regulatory enforcement on AFB1 limits within food supply chains and strengthen post-harvest drying and storage in Nigeria.

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