Aflatoxin Profiles and Their Public Health Risks in Raw Meat Samples from Minna Metropolis, Nigeria

Shehu-Adisa, M.[1*], Bala, J. D.[1,2], Auta, H. S.[1,2], James, S.[3]

[1]*Africa Center of Excellence for Mycotoxins and Food Safety, Federal University of Technology, Minna, Niger State, Nigeria.*
[2]*Department of Microbiology, Federal University of Technology, Minna, Niger State, Nigeria*
[3]*Department of Food Science and Technology, Federal University of Technology, Minna, Niger State, Nigeria*

***Corresponding author:** muslimah1432@yahoo.com **Phone number:** +2347034219235

ABSTRACT

Background: *Meat, including muscle and fats, is vital for human nutrition but when contaminated with harmful toxins like aflatoxins, posing health risks to the consumers.*
Objective: *This study profiles aflatoxin concentrations and its public health risks in raw meat sourced from abattoirs within Minna metropolis.*
Methodology: *High-performance liquid chromatography and fluorescence screening was employed to analyze Aflatoxins in randomly collected meat samples consisting of beef, mutton, and chevon from six abattoirs.*
Results: *The presence of Aflatoxin G1 (AFG1), Aflatoxin G2 (AFG2) and Aflatoxin B1 (AFB1) were very low and some fall threshold limit. However, samples from the UK abattoir contained detectable levels of AFG1, AFG2 and AFB1, resulting in a total aflatoxin concentration of 0.88 ± 1.18 µg/kg. Chanchaga samples showed the highest mean AFG1 concentration (1.00 ± 2.00 µg/kg), while Maitumbi and Tunga had low levels of AFG1 or AFG2, with totals of 0.25 ± 0.39 µg/kg and 0.35 ± 0.70 µg/kg, respectively. Tayi and Bosso samples were below the limit of detection for all aflatoxins. Among meat types, chevon had the highest mean aflatoxin levels, with a total of 0.85 ± 1.59 µg/kg, followed by beef and mutton, which had lower levels. AFB1 and AFB2 were not detected in any samples. Risk assessment indicated that children have higher estimated daily intake and cancer risk from aflatoxin exposure compared to adults, with beef in children presenting the highest potential risk.*
Conclusion: *To mitigate health risks, especially among children, there is an urgent need to enhance feed quality control.*

Keywords: Mycotoxins, Aflatoxins, profiles, Public health risks, Raw meat

Doi: https://dx.doi.org/10.4314/njns.v47i2.15

INTRODUCTION

Meat comprises animal tissue, skeletal muscle, and associated fats consumed as food. It contains proteins (with all essential amino acids), vitamins (A, B_{12}, B_6, D, and E), and minerals (iron and zinc), which are very important for human growth and well-being [1]. Meat composition encourages the growth of microorganisms and may predispose the meat to contamination if appropriate measures are not observed [2,3]. Contamination of meat and meat products is readily caused by a variety of biological, chemical, and physical factors, and occasionally by mycotoxins [4,5]. Aflatoxins are one of the most potent and prevalent mycotoxins, primarily produced by *Aspergillus flavus* and *Aspergillus parasiticus*. Aflatoxin contamination of meat may compromise its nutritional benefits and thereby adversely affect the health and nutritional status of

both human and animal consumers. Aflatoxins are known for their carcinogenic, mutagenic, and immunosuppressive properties, making their presence in food products a major public health concern worldwide. Among the naturally occurring aflatoxins, aflatoxin B1 is the most toxic due to sufficient evidence of its carcinogenicity in humans, particularly its association with hepatocellular carcinoma [6]. In Nigeria, particularly in a region like Minna Metropolis, the consumption of contaminated foodstuffs such as raw meat may serve as a potential pathway for aflatoxin exposure. Despite the critical health implications, limited data exist regarding the prevalence of aflatoxins in meat products in this area. This study aims to profile the levels of aflatoxins in raw meat samples from Minna Metropolis and assess the associated public health risks. Understanding these profiles is essential for developing effective intervention strategies to safeguard public health and ensure food safety standards are maintained.

MATERIALS AND METHODS

The study was carried out in six different abattoirs within Minna metropolis, which is the capital city of Niger State, Nigeria. Niger State is located in the North-central geo-political zone of Nigeria. It is located at latitude 10°00N and longitude 6°01N. Having a Human population of about 4.2 million people [7]. The state has an estimated cattle population of about 2.4 million, 1.8 million sheep and 2.1 million goats, and over 5 million local and commercially raised poultry [8]. It experiences two distinct seasons: a rainy season, which spans between April and October, and a dry season between October and November, with mean annual rainfall of about 1600 mm and average lowest and highest temperatures of about 27 °C and 39 °C respectfully.

Collection of Samples

A total of 54 samples of raw meat from three different meat types (beef, mutton and chevon) were randomly selected from six different abattoirs in Minna metropolis. These Abattoirs include: Chanchaga, Tunga, Uk Bello, Maitunbi, Tayi, and Bosso Communities. For each type of meat, three samples were collected in each abattoir. That is, three beef, three mutton, and three chevon collected in each of the six abattoirs, making a total of 54 samples. The weight of each sample was taken and placed in a clean, dry sterile plastic container, sealed and properly labelled. The samples were kept in ice- box and conveyed to the laboratory at the Federal University of Technology, Minna, for analysis.

Sample Processing

High-Performance Liquid Chromatography (HPLC) and a fluorescence screening method were used to determine mycotoxin serotype (aflatoxins) from raw meat using the method described by [9]. Briefly, sample (5gm) of raw meat was weighed into a Falcon tube and extracted with a solvent mixture of 1 g of sodium chloride and 20 mL of methanol (80 %) mixed at high speed for 3 min. The extract was filtered through a Whatman No. 113 filter paper, and 2 mL of it was pipetted and diluted with 10 mL of phosphate-buffered saline (PBS), thoroughly mixed, and centrifuged for 10 min at 10,000 rpm to elute. The sample extract was applied to the conditioned immunoaffinity column and allowed to adsorb onto the column. Once the entire extract had passed through, the column was then washed with 5 mL of phosphate-buffered saline (PBS). The aflatoxins were eluted in a 2-step procedure: First, 1.0 mL of 100% methanol was applied to the immunoaffinity column (IAC) and allowed to flow through under gravity. Then, the eluate was collected in an amber glass vial. For the second elution, after waiting for 1 min, 1 mL of water was passed through the column and collected in the same vial to give a 2 mL total volume. This eluate was injected into the HPLC- fluorescence analysis.

Evaluation of Potential Health Risk: Dietary Exposure to Aflatoxin B1 (AFB1)

The dietary exposure of the Minna, Niger State population to total aflatoxin and its associated health risk was analysed. The estimated daily intake (EDI) was calculated using previous adopted approach by [10], as shown in the formula in Equation 1:

$$EDI = \frac{\text{Daily meat intake} \times \text{average AFs concentration}}{\text{body weight (kg)}} \quad \ldots\ldots 1$$

The estimated daily intake (EDI) considered the mean concentration of aflatoxins detected from the meat samples obtained from the six different abattoirs within Minna metropolis, Nigeria. The calculation also considered the quantity of meat ingested daily and the average body weight. The daily meat consumption was based on National Dietary Data: 4.1 grams of beef, 3.5 grams of chevon, and 0.3 grams of mutton [11]. An average body weight of adults and children was considered to be 60 kg and 10 kg, respectively, as reported by [12]. The result is expressed in nanograms per kilogram of body weight per day (ng/kg BW/day). This formula aid to determine how much aflatoxin an individual could consume daily via meat ingestion.

Risk Characterization (Risk Assessments) of Total Aflatoxins via Meat Consumption

Risk characterization was assessed using methods such as margin of exposure analysis and cancer risk assessment [13]. These methods show the possibility of a negative impact of aflatoxins on a human population.

The Estimate of Potential Health Risks Associated with Aflatoxin Exposure

Margin of Exposure (MOE) method was applied to evaluate the potential health risks associated with this exposure, particularly the cancer risk linked to genotoxic compounds like AFB1. This method is recommended by the European Food Safety Authority (EFSA) [14], and it involves dividing the benchmark dose lower limit (BMDL10) by the EDI. For AFB1, EFSA established the BMDL10 as 170 ng/kg BW/day, which represents a dose that leads to a 10% cancer incidence rate in animal studies (see eqn 2).

$$MOE = \frac{BMDL10}{EDI} \quad \text{.....2}$$

The Estimate of Liver Cancer Risk from Aflatoxin Exposure

To assess potential risk of liver cancer from aflatoxin exposure among Minna, Niger State population. Cancer risk is defined as the number of potential cases per 100,000 people per year and is calculated by multiplying the estimated daily intake (EDI) by the liver cancer potency factors for hepatitis B virus surface antigen (HBsAg) [15]. The FAO/WHO Expert Committee on Food Additives [16, 17] set hepatocellular carcinoma potency (HCC) factors at 0.30 cases per 100,000 persons per year per ng of aflatoxin/kg bw/day for infected individuals with chronic HBV and 0.01 for individuals without chronic HBV infection. This body considered the prevalence of chronic hepatitis B virus (HBV) infection, which significantly enhances the carcinogenic effect of AFB1. To apply the potency method within the Minna population, a study in Nigeria found that 13.2% of Nigerians are hepatitis virus positive and 86.8% hepatitis virus negative [18].

Therefore,

carcinogenic potency = (0.3 × hepatitis virus positive) + (0.01 × hepatitis B virus negative. 3a

carcinogenic potency = (0.3 × 13.2%) + (0.01 × 86.8%) = 0.04828 .....3b

Cancer Risk = Cancer potency × Exposure (EDI).....4

Cancer Risk (cases/year/100,000 people) =

[(0.01 × 86.8%) + (0.30 × 13.2%)] × EDI 5

This calculation provides a clearer picture of the public health burden from long-term exposure to AFB1 through meat consumption, especially in settings with high HBV prevalence.

Data Analysis

Data generated from the study were analyzed by one-way analysis of variance (ANOVA). Where significant differences were observed, the treatment means were separated using Duncan's multiple range test (DMRT). A P value ≤ 5 % was considered statistically significant.

RESULTS

Aflatoxin Concentrations Across Meat Samples in All Locations

Table 1 revealed that aflatoxin concentrations across meat samples in all locations were generally low, with most samples having aflatoxin concentrations below the limit of detection (LOD). UK samples had detectable levels of AFG_1 (0.60 ± 1.19 μg/kg), AFG_2 (0.23 ± 0.45 μg/kg), and AFB_1 (0.05 ± 0.01 μg/kg), resulting in a total aflatoxin concentration of 0.88 ± 1.18 μg/kg. Chanchaga samples showed the highest mean AFG_1 concentration (1.00 ± 2.00 μg/kg), while Maitumbi and Tunga had low detectable levels of AFG_1 or AFG_2, with totals of 0.25 ± 0.39 μg/kg and 0.35 ± 0.70 μg/kg, respectively. Tayi and Bosso samples were below the limit of detection for all aflatoxins. The contamination pattern indicates that while aflatoxins were occasionally present, none of the samples exceeded the EU regulatory limits for AFB_1 (5 μg/kg) or total aflatoxins (10 μg/kg).

Aflatoxin Contamination Across Different Meat Types

Table 2 presents the levels of aflatoxin contamination across different meat types and shows that the aflatoxin concentrations in the samples were lower than the regulatory safe thresholds. Among the meat types, chevon exhibited the highest mean levels of AFG1 (0.67 ± 1.64 μg/kg) and AFG2 (0.18 ± 0.37 μg/kg), resulting in the highest total aflatoxin concentration (0.85 ± 1.59 μg/kg). The beef samples showed moderate detectable levels of AFG1 (0.40 ± 0.94 μg/kg) and AFG2 (0.23 ± 0.47 μg/kg), with a corresponding total aflatoxin concentration of 0.32 ± 0.83 μg/kg. In contrast, mutton displayed lower levels of contamination, with detectable AFG_1 (0.14 ± 0.34 μg/kg) and negligible AFG_2, yielding a total aflatoxin level of 0.17 ± 0.33μg/kg. Aflatoxins AFB_1 and AFB_2 were not detected in any of the meat types. These

findings indicate that chevon contributed the most to aflatoxin exposure among the evaluated meat types, followed by beef, while mutton showed the lowest contamination levels. Importantly, all measured aflatoxin concentrations were well below the European Union regulatory limits for AFB1 (5 μg/kg) and total aflatoxins (10 μg/kg), suggesting no immediate food safety concern.

Table 1: Aflatoxin Concentrations in Meat Samples per Location

Location	AFG1 (μg/kg)	AFG2 (μg/kg)	AFB1 (μg/kg)	AFB2 (μg/kg)	Total (μg/kg)
UK	0.60 ± 1.19^{b}	0.23 ± 0.45^{b}	0.05 ± 0.01^{b}	0.00 ± 0.00^{a}	0.88 ± 1.08^{b}
Tunga	0.00 ± 0.00^{a}	0.35 ± 0.70^{b}	0.00 ± 0.00^{a}	0.00 ± 0.00^{a}	0.35 ± 0.70^{ab}
Tayi	0.00 ± 0.00^{a}	0.00 ± 0.00^{a}	0.00 ± 0.00^{a}	0.00 ± 0.00^{a}	0.00 ± 0.00^{a}
Maitumbi	0.21 ± 0.41^{ab}	0.04 ± 0.09^{a}	0.00 ± 0.00^{a}	0.00 ± 0.00^{a}	0.25 ± 0.39^{ab}
Chanchaga	1.00 ± 2.00^{c}	0.00 ± 0.00^{a}	0.00 ± 0.00^{a}	0.00 ± 0.00^{a}	1.00 ± 2.00^{c}
Bosso	0.00 ± 0.00^{a}	0.00 ± 0.00^{a}	0.00 ± 0.00^{a}	0.00 ± 0.00^{a}	0.00 ± 0.00^{a}

AFG_1: Aflatoxin G_1, AFG_2: Aflatoxin G_2. AFB_1: Aflatoxin B_1, AFB_2: Aflatoxin B_2. Means sharing the same superscript letter are not significantly different; different letters indicate significant differences ($p < 0.05$).

Table 2: Aflatoxin Concentrations in the Meat Type

Meat Type	AFG1 (μg/kg)	AFG2 (μg/kg)	AFB1 (μg/kg)	AFB2 (μg/kg)	Total (μg/kg)
Mutton	0.27 ± 0.44^{a}	0.06 ± 0.11^{a}	0.00 ± 0.00^{a}	0.00 ± 0.00	0.33 ± 0.50^{a}
Chevon	0.67 ± 1.64^{b}	0.18 ± 0.37^{a}	0.00 ± 0.00^{a}	0.00 ± 0.00	0.85 ± 1.59^{b}
Beef	0.14 ± 0.34^{a}	0.03 ± 0.08^{a}	0.00 ± 0.00^{a}	0.00 ± 0.00	0.17 ± 0.33^{a}

AFG_1: Aflatoxin G_1, AFG_2: Aflatoxin G_2. AFB_1: Aflatoxin B_1, AFB_2: Aflatoxin B_2. Means sharing the same superscript letter are not significantly different; different letters indicate significant differences ($p < 0.05$).

The Estimated Daily Intake (EDI), Margin of Exposure (MOE), and Cancer Risk from Aflatoxin in Different Neat Types Across Age Groups

Table 3 shows the estimated daily intake (EDI), margin of exposure (MOE), and cancer risk from aflatoxin in chevon, mutton, and beef across children and adults. For chevon, children had an EDI of 0.030 μg/kg bw/day compared with adults at 0.050 μg/kg bw/day. The MOE was much lower in children (566.7) than in adults (3400). Cancer risk followed the same pattern, with 0.014 cases per 100,000 persons in children and 0.002 in adults. In mutton, children had an EDI of 0.01 μg/kg bw/day, while adults had only 0.001 μg/kg bw/day. The MOE for children was 17,000 compared with 170,000 in adults. Cancer risk was slightly higher in children (0.0005) than in adults (0.00005). For beef, children showed an EDI of 0.13 μg/kg bw/day, which was higher than adults at 0.022 μg/kg bw/day. The MOE values were 1307.7 in children and 7727.3 in adults. Cancer risk in children (0.060) was notably higher than in adults (0.001). This indicates that children consistently had higher estimated daily intake and cancer risk across all meat types, with lower margins of exposure compared to adults. Beef in children showed the highest EDI (0.13 μg/kg bw/day) and cancer risk (0.060/100,000 persons/year), while mutton in adults had the lowest values across all parameters. This highlights distinct differences in aflatoxin exposure between meat types and age groups.

Table 3: Estimated Daily Intake, Margin of Exposure, and Cancer Risk from Aflatoxin in Different Meat Types Across Age Groups

Meat Type	Age	TAF	Av. BW	IR(g/person/day)	EDI	MOE	Cancer risk (HCC/100,000 persons/year)
Chevon	Child	0.85	10	3.5	0.030	566.7	0.014
	Adult	0.85	60	3.5	0.050	3400	0.002
Mutton	Child	0.17	10	0.3	0.01	17000	0.0005
	Adult	0.17	60	0.3	0.001	170000	0.00005
Beef	Child	0.32	10	4.1	0.13	1307.7	0.060
	Adult	0.32	60	4.1	0.022	7727.3	0.001

TAF = Total Aflatoxin, Av. BW = Average Body weight, IR = Ingestion Rate, EDI = Estimated daily intake, MOE = Margin of Exposure

DISCUSSION

Aflatoxin Concentrations in the Sampling Locations Across Meat Samples

The generally low levels of aflatoxins detected in this study across locations and meat types are consistent with the idea that meat itself is not typically a major aflatoxin reservoir compared with plant-based foods or feeds but may reflect indirect exposure through contaminated animal feeds and environmental conditions that favor fungal proliferation [19]. Aflatoxins are produced by *Aspergillus* species under warm, humid conditions and are well documented in food commodities such as cereals, nuts, and spices in Nigeria, where high moisture and sub-optimal storage promote fungal growth and toxin formation; for example, studies across Nigerian markets have shown high aflatoxin occurrence in staple foods, often correlated with moisture content and storage practices [20,21]. In contrast, aflatoxin levels in meat from this study remain low, likely because aflatoxins originate primarily in feedstuffs and are not appreciably accumulated in muscle tissue; this interpretation aligns with older Nigerian research showing mycotoxigenic fungi present in meat but generally low toxin levels when compared with dietary staples [22]. Comparatively, studies from other regions also illustrate that meat products tend to show lower aflatoxin contamination relative to feeds or highly susceptible crops: for example, surveys of processed meats in Egypt detected aflatoxins in some products but at varied and often low levels, suggesting that contamination may be more sporadic and related to ingredient quality rather than intrinsic to meat [23,24].

Levels of Aflatoxin Contamination Across Different Meat Types

Differences in contamination across locations and meat types observed here may be due to variations in animal diet, feed sources, and handling; meat types receiving feeds with higher mould contamination are more likely to show detectable residues. The higher aflatoxin burden in chevon and beef samples in this study could reflect feed differences or farm-to-market handling variations compared with other meat types. Environmental conditions in Nigeria's tropical climate, high temperature and high humidity, are known to predispose agricultural and feed materials to aflatoxin contamination, which in turn may influence low-level residues found in animal products. Importantly, despite detectable aflatoxins in some samples, none exceeded international regulatory limits (EU limits for AFB1 and total aflatoxins), which supports the conclusion that the current contamination patterns pose a low consumer risk via direct meat consumption, meaning that the meat types within Minna are safe for consumption, although chronic exposure through the broader diet remains a concern in Nigeria and similar regions where aflatoxin occurrence in feed and plant foods is widespread.

Estimated Daily Intake (Edi), Margin of Exposure (Moe), and Cancer Risk from Aflatoxin in Chevon, Mutton, and Beef Across Children and Adults

The assessment of potential health risk via estimated daily intake, margin of exposure, and cancer risk from aflatoxin in different meat types across age groups indicate that children are at a greater risk of aflatoxin exposure from meat consumption compared with adults, which is consistent with previous research showing that children are more vulnerable to foodborne toxins due to their lower body weight and higher food intake per kilogram of body weight [25]. The higher estimated daily intake (EDI) values in children across chevon, mutton, and beef suggest that the dietary burden of aflatoxin is disproportionate in younger age groups. This is concerning because aflatoxins are potent carcinogens, and long-term exposure, even at low doses, can increase the risk of liver cancer [26]. The high exposure from beef in children reflects both consumption patterns and the bioaccumulation of aflatoxins in livestock feed. Cattle often consume large amounts of maize and groundnut-based feeds, which are highly susceptible to *Aspergillus* contamination [27]. When these contaminated feeds enter the animal diet, aflatoxins or their metabolites, particularly aflatoxin M1, are transferred into edible tissues. This explains the higher EDI and cancer risk associated with beef compared to mutton or chevon. By contrast, small ruminants such as goats and sheep are often raised on forage-based diets with less dependence on stored grains, which may reduce aflatoxin accumulation in their tissues [28]. The lower margins of exposure (MOE) in children further highlight the heightened health concern. According to the European Food Safety Authority (EFSA, 2020), a MOE below 10,000 indicates a potential health risk. The values observed in children, especially for beef and chevon, fall well below this threshold, highlighting the urgency for interventions. Adults showed comparatively safer MOE values, particularly in mutton, where exposure and risk were minimal. This aligns with the idea that both dietary diversity and lower intake per kilogram of body weight reduce adult susceptibility.

Children remain the most at-risk group for aflatoxin-related health effects from meat consumption. This is attributed not only to their physiology

but also to the contamination pathways from animal feed into the food chain. Strengthening feed quality monitoring, promoting proper grain storage, and encouraging dietary diversification could reduce aflatoxin burden in both livestock and humans.

CONCLUSION

This study revealed that aflatoxin levels in raw meat within Minna metropolis are generally low and fall well below the Commission regulation. This indicates that the meat is safe for consumption. Although the detected aflatoxin levels in meat samples did not exceed international safety limits, the higher estimated exposure and lower margin of exposure observed in children raise significant health concerns, given their increased vulnerability to the carcinogenic effects of aflatoxins. To mitigate health risks, especially among vulnerable populations like children, there is an urgent need to enhance feed quality control, improve storage practices, and promote dietary diversification. Implementing these measures can help further reduce aflatoxin exposure in animal products and safeguard public health in Nigeria

ACKNOWLEDGEMENT

Firstly, the authors wish to express their gratitude to the African Center of Excellence for Mycotoxins and Food Safety, Federal University of Technology, Minna, for the sponsorship of the study. The authors would also like to express their gratitude to their supervisors and participants in the research.

REFERENCES

1. Zerabruk, K., Retta, N., Muleta, D., & Tefera, A. T. (2019). Assessment of microbiological safety and quality of minced meat and meat contact surfaces in selected butcher shops of Addis Ababa, Ethiopia. *Journal of Food Quality, 2019*, 1–9.
2. Nel, S., Lues, J. F. R., Buys, E. M., & Venter, P. (2004). The personal and general hygiene practices in the deboning room of a high-throughput red meat abattoir. *Food Control, 15*, 571–578. https://doi.org/10.1016/j.foodcont.2003.09.004
3. Mallhi, I. Y., Sohaib, M., Khan, A. U., & Nawaz, M. (2019). Evaluating food safety knowledge, practices, and microbial profile of meat in abattoirs and butchery shops in Lahore, Pakistan. *Journal of Food Safety, 39*, e12612. https://doi.org/10.1111/jfs.12612
4. Ko, E. K., Heo, E. J., Kim, Y. J., Park, H. J., Wee, S. H., & Moon, J. S. (2013). Evaluation of microbiological contamination level of raw beef from retail markets in Seoul, Korea. *Korean Journal of Food Science and Animal Resources, 33*, 403–410.
5. Kim, H. J., Kim, D., Song, S. O., Goh, Y. G., & Jang, A. (2016). Microbial status and guidelines for raw chicken distributed in Korea. *Korean Journal of Poultry Science, 43*, 235–242. https://doi.org/10.5536/KJPS.2016.43.4.23
6. International Agency for Research on Cancer. (2012). Aflatoxins. In *IARC monographs on the evaluation of carcinogenic risks to humans: Volume 100F. Chemical agents and related occupations*. International Agency for Research on Cancer.
7. National Population Commission. (2006). *Population census of the Federal Republic of Nigeria: Preliminary report*. http://www.population.gov.ng
8. Aliyu, M., Chinasa, O., & Daniel, A. (2024). *Niger begins 2024 livestock vaccination*. Federal Radio Corporation of Nigeria.
9. Abd El-Tawaab, A. A., El-Hofy, F. I., Mahmoud, A. H., & Rashed, D. M. (2019). Mycotoxin residues in different chicken products by HPLC and their inactivation using gamma radiation. *International Journal of Pharmaceutical Research & Allied Sciences, 8*(4), 71–81.
10. Kortei, N. K., Annan, T., Kyei-Baffour, V., Essuman, E. K., Boakye, A. A., Tettey, C. O., & Boadi, N. O. (2022). Exposure assessment and cancer risk characterization of aflatoxin M1 (AFM1) through ingestion of raw cow milk in southern Ghana. *Toxicology Reports, 9*, 1189–1197.
11. Food and Agriculture Organization of the United Nations. (2022). *Food balance: Livestock and fish primary equivalent*. FAOSTAT.
12. Jamiu, S. A., Olorunfemi, M. F., & Adesina, O. B. (2025). Assessment of health risks associated with mycotoxin exposure in Nigeria. *Journal of Food Safety and Quality, 16*(2), 112–120.
13. Geleta, G. S., Nugussa, A., Faye, G., & Ragassa, G. (2024). Assessment of human health risks from aflatoxin M1 in raw milk: A study from North Shewa Zone, Oromia Region, Ethiopia. *Environmental Health Insights, 18*, 1–10.
14. EFSA Panel on Contaminants in the Food Chain (CONTAM), Schrenk, D., Bignami, M., Bodin, L., Chipman, J. K., del Mazo, J., Grasl-Kraupp, B., Hogstrand, C., Hoogenboom, L. R., Leblanc, J.-C., Nebbia, C. S., Nielsen, E., Ntzani, E., Petersen, A., Sand, S., Schwerdtle, T., Vleminckx, C., Marko, D., Oswald, I. P., . . . Wallace, H. (2020). Risk assessment of

aflatoxins in food. *EFSA Journal, 18*(3), 6040. https://doi.org/10.2903/j.efsa. 2020.6040
15. Udovicki, B., Đekić, I., & Rajković, A. (2021). Mycotoxins in food and feed: A review on risk assessment and management. *Food Control, 124*, 107872.
16. Food and Agriculture Organization of the United Nations, & World Health Organization. (1998). *Safety evaluation of certain food additives and contaminants* (Joint FAO/WHO Expert Committee on Food Additives Report No. 40).
17. Joint FAO/WHO Expert Committee on Food Additives. (2020). *Summary and conclusions of the 83rd meeting of the Joint FAO/WHO Expert Committee on Food Additives* (JECFA/83/SC). World Health Organization.
18. Wenndt, A., Mutua, F., Grace, D., Thomas, L. F., & Lambertini, E. (2023). Quantitative assessment of aflatoxin exposure and hepatocellular carcinoma (HCC) risk associated with consumption of select Nigerian staple foods. *Frontiers in Sustainable Food Systems, 7*, 1128540.
19. Agboola, Y. J., Oluwakanyinsola, S. K., Kehinde, O. E., Agboola, J. E. O., & Olasupo, O. A. (2023). Occurrence of aflatoxins in Nigerian foods: A review. *Hrvatski časopis za prehrambenu tehnologiju, biotehnologiju i nutricionizam, 18*(1–2), 29–36.
20. Oyedele, O. A., Ezekiel, C. N., Sulyok, M., Adetunji, M. C., Warth, B., Atanda, O. O., & Krska, R. (2017). Mycotoxin risk assessment for consumers of groundnut in domestic markets in Nigeria. *International Journal of Food Microbiology, 251*, 24–32.
21. Adamu, S. H., Haruna, S. G., Sanda, N. B., & Yusuf, A. U. (2025). Exploring aflatoxin contamination in Nigerian vegetables: A comprehensive review of current insights, drivers, and management strategies. *International Journal of Research and Scientific Innovation, 12*(9).
22. Popescu, R. G., Rădulescu, A. L., Georgescu, S. E., & Dinischiotu, A. (2022). Aflatoxins in feed: Types, metabolism, health consequences in swine and mitigation strategies. *Toxins, 14*(12), 853.
23. El-Gohary, I., Abd-Elsalam, R., Fadal, N., & Mahmoud, M. (2022). Aflatoxin M1 inducing genotoxicity and pathological lesions in organ meats, liver of cattle sampled from El-Basatin abattoir, Egypt. *Journal of Microbiology, Biotechnology and Food Sciences*. https://doi.org/10.55251/jmbfs.3527
24. Hassan, M., Abd El Aziz Hassan, A., Hasanine Tartor, Y., & Farouk Ali, S. (2014). Aflatoxin-producing moulds and aflatoxin residues in meat and meat products in Egypt. *Zagazig Veterinary Journal, 42*(3), 43–55.
25. Wu, F. (2015). Global impacts of aflatoxin in maize: Trade and human health. *World Mycotoxin Journal, 8*(2), 137–142.
26. International Agency for Research on Cancer. (2012). Aflatoxins. In *IARC monographs on the evaluation of carcinogenic risks to humans: Volume 100F. Chemical agents and related occupations*. International Agency for Research on Cancer.
27. Matumba, L., Sulyok, M., Njoroge, S., et al. (2015). Multiple mycotoxin contamination of maize across the value chain in Malawi. *Food Control, 52*, 92–97.
28. Kang'ethe, E. K., & Lang'a, K. A. (2009). Aflatoxin B1 and M1 contamination of animal feeds and milk from urban centers in Kenya. *African Health Sciences, 9*(4), 218–226.