Implication of Aflatoxin (*Aspergillus flavus*) Reduction Strategies in Maize Based Poultry Feeds on Food and Nutrition Security

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ABSTRACT

Aflatoxin contamination in maize-based poultry diets is a serious threat to poultry productivity and public health. This study evaluated the efficacy of graded levels of ginger (Zingiber officinale) powder as an aflatoxin-reducing agent in broiler diets. Two maize sources (Aflasafe maize and Aspergillus flavus-infested maize) were formulated into five dietary treatments: T1 (Aflasafe maize with 0% ginger), T2 (infested maize +5% ginger), T3 (infested maize +10% ginger), T4 (infested maize +15% ginger), and T5 (infested maize +20% ginger). A total of 180, Agri-tech day-old broiler chicks were randomly allocated to treatments and monitored over 8 weeks. Growth performance, hematological indices, serum biochemistry, and bio-economic indices were measured. Results revealed that higher inclusion levels of ginger significantly improved feed intake, weight gain, and feed conversion ratio (FCR) compared to infested maize without ginger supplementation. Hematological parameters including packed cell volume and total leukocyte count were significantly improved in T3–T5. Serum biochemical indices showed reduced serum ALT and AST in ginger-supplemented groups, indicating hepato-protective effects. Bio-economic analysis revealed superior profitability in T3 and T4 relative to T2. The study concluded that dietary inclusion of ginger up to 15% effectively mitigates aflatoxin toxicity while improving broiler productivity and profitability.

Keywords: *Aflatoxin, ginger, broilers, serum biochemistry, performance, bio-economics*

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INTRODUCTION

Maize (*Zea mays*) is the primary source of energy in poultry diets accounting for over 50% of the total feed ingredients used in broiler and layer production systems and 85-90% in cooked maize in human, 90% plus in maize flour and 60-75% in raw and unprocessed maize kernel in Nigeria with other many African countries (FAO, 2003; Ezekiel *et al.*, 2021). Aflatoxins are carcinogenic, toxic and

secondary metabolites primarily produced by *Aspergillus flavus* and *Aspergillus parasiticus*. These toxins are of major concern in global food and feed chains due to their wide distribution and significant impacts on animal productivity and public health. In developing countries, especially in Nigeria and sub-Saharan Africa, aflatoxin contamination in maize and maize-based feeds poses a serious threat to poultry production and food security (Okoth, 2021; Misihairabgwi *et al*., 2022). Its susceptibility to aflatoxin contamination during cultivation, harvesting, storage, and feed processing severely compromises feed quality. The ingestion of aflatoxin-contaminated feed by poultry has been associated with reduced feed intake, poor weight gain, immunosuppression, hepatotoxicity, increased susceptibility to diseases, reduced egg production, and higher mortality (Chilaka *et al*., 2020; Udom *et al*., 2023).

In response to these challenges, a range of aflatoxin reduction strategies have been proposed and tested, including pre- and post-harvest interventions, improved storage systems, and the incorporation of aflatoxin binders and biodegradation agents into poultry feed. These include natural clays (e.g., bentonite), activated charcoal, yeast cell wall components, and microbial detoxifiers (Kolawole *et al.,* 2022; Wu *et al.,* 2023). However, the effectiveness, cost-efficiency, and safety of these strategies remain variable under field conditions, necessitating more localized, systematic evaluation.

Understanding the implications of applying these strategies within maize-based poultry production systems is critical for enhancing animal productivity, protecting consumer health, and achieving broader food and nutrition security goals. This study is aim to investigate the effects of ginger on the aflatoxin infected maize broiler diets so as to investigate the effects on production performance, Heamatology, Serum chemistry and bio economic parameters of broilers fed different aflatoxin reduced maize meal-based diets.

MATERIALS AND METHODS

Procurement and processing of Ginger (*Zingiber officinale*).

Ginger (*Zingiber officinale*) Meal (GIM)

Fresh ginger rhizomes was purchased from Lafia market, Nasarawa State. The cleaned rhizomes was chopped into tiny pieces and kept in a hot ovum at 71°C for two days, air dried and later ground in a local machine in order to obtain the dried ground smooth powder and stored separately in an air tight polyethene bag adopted by (Hassan *at al.* 2015; Ari *et al.,* 2020).

Phytochemical screening of the Ginger (*Zingiber officinale*)

The qualitative phytochemical analysis of the Ginger (*Zingiber officinale*) was carried out. The aqueous and methanol extracts were separately screen for the presence of bioactive constituents such as tannins, saponins, alkaloids, flavonoids, glycosides, reducing sugar, resins, oils, steroids, terpenoids, acidic compounds, anthraquinon and coumorins using standard phytochemical techniques as described by Oluduro (2012).

Test Ingredients and Experimental diets/ Infestation of Maize with *Aspergillus flavus* for the experiment

Maize grains were procured from open market at Lafia which were serve as test ingredient and infested with isolates of *Aspergillus flavus* for contamination. The samples were properly packed according to IATA (International Air Transport Association) standards and subsequently was send for *Aspergillus flavus* test using HPLC techniques as a method adopted by (Zhang, Li, and Zhang, 2011) or using Elisa method as adopted by (Kos and Krska 2003).

Dietary treatments were as follows: T1, T2, T3, T4 and T5 thus representing experimental treatment groups which had: Aflasafe maize with 0% ginger (T1), infested maize with 5% ginger (T2), infested maize with 10% ginger (T3), infested maize with 15% ginger (T4) and infested maize with 20% ginger (T5). The maize alongside other ingredients were milled using a laboratory scale hammer miller and sieved through a 30mm mesh screen according to the methods.

The incorporation of test ingredients served as the main source of variations. The starter diets were fed for four (4) weeks (1- 28 d) brooding phase and the finisher diets were fed for three (3) weeks (29- 50 d). The experimental diets were formulated using a least cost feed formulation software *Feedwin*.

Laboratory Analysis of feeds

Aflatoxin test for experimental diets

All the experimental diets for this study were subjected to Aflatoxin test, particularly *Aspergillus flavus.*

Experimental design

Five experimental diets for both starter and finisher phases (T1, T2, T3, T4 and T5) were formulated using *Feedwin Software*. The test ingredients were obtain from Lafia maize. The experimental diets were compounded such that they would meet the nutrient requirements of broilers as described by NRC (1996) and Oluyemi and Robert (2002).

Experimental Birds and Management

A total of 180, Agri-tech broiler chicks were randomly allotted into 5 dietary treatment groups of three replicates each. Dietary treatments were as follows: T1, T2, T3, T4

and T5.The incorporation of test ingredients were served as the main source of variations.

Data collection

Performance parameters

The following parameters were measured and computed from the data generated from daily and weekly recordings during the feeding trials: feed intake, body weight, body weight gain, feed conversion ratio (feed: gain) and mortality.

Heamatology and Serum biochemical analysis

At the end of the fourth and eight weeks of the experiment, 3mls of blood were collected from the wing vein of birds per replicate then immediately transfered into 2 sterile test tubes; 1ml into the first tube containing EDTA for haematological determination and 2mls into the second tube without anti-coagulant for serum biochemical determination. The first with EDTA will be used to determine RBC, WBC using the improved Neubauer haemocytometer as described by Dacie and Lewis, (1991). PCV was determined using the microhaematocrit method (Bernard *et al.,*2000) and haemoglobin (HB) using cyanometheoglobin method according to Cole, (1986).

Data management and analysis

Data was collected and stored in hard and soft copies using data base applications Microsoft excel on daily and weekly bases depending on parameters measured. All data generated were subjected to analysis of variance (ANOVA) using SPSS (2012) version 23 which determined the effect ginger in the dietary treatments. A significant differences ($P<0.01$) were observed, means were separated using (Duncan, 1955) as described by Steel and Torries (1980). Each experimental bird was randomly assigned to a test diet in a Completely Randomized Design (CRD).

The following statistical model will be employed:

$Y_{ij} = \mu + T_i + e_{ij}$

Were Y_{ij} = Individual Observation

μ = Population Mean

T_i = Treatment Effect

e_{ij} = Random Error

RESULTS AND DISCUSSION

The phytochemical evaluation as indicated in (Table 1) showed that the active constituents found in ginger the presence of anthraquinone, tannins, steroids, cardiac glycosides, flavonoids, alkaloids terpenes and saponins. The extract for solvents methanol extract showed more number of constituents when compare with aqueous extract. These bioactive constituents in Ginger have been used in the treatment of many diseases and disorders (Chinwe *et al.* (2012; Shipra *et al.,* 2012). Ginger has been found to enhance pancreatic lipase activity, intestinal lipase, disaccharide for growth promoting feed additives (Platel and Srinicasan, 2000) as well as in the development of resistance against microbial pathogens. The proximate composition of ginger is shown in (Table 2). It shown that ginger contained 4.69 DM, 8.31CP%, 17.54 EE%, 10.31 ASH%, 5.65 CF%, 53.5 NFE%. The mineral contents calcium and Phosphorus (Table 2). The nutrient composition of the experimental diets were shown in (Table 3). Data on performance as well as the economics of production of broiler chickens on the various dietary level of ginger (Tables 3 and 4). Table 3 gives the nutrient composition of the experimental diets, the calculated crude protein for treatment diets, the calculated metabolisable energy 3000.02kcal/kg. Performance of the different levels of ginger inclusion is presented in (table 3). Among the various parameters measured.

Table 1: Phytochemical Constituents of Ginger (Zinger officinale).

	Ginger	
Parameter	**Aqueous**	**Methanol**
Anthraquinone	-	+
Tannins	-	+
Steroids	+	-
Cardiac glycosides	+	+
Flavonoids	+	+
Alkaloids	-	+
Saponins	-	+

+ indicate presence, - indicates absent

Table 2: Proximate composition of Ginger (*Zingiber officinale*) Meal (%GIM).

Nutrients	**(%GIM)**
Dry Matter (DM)	4.69
Crude Protein	8.31
Ether Extract	17.54
Ash	10.31
Crude fiber	5.65
Nitrogen free extract (NFE)	53.5
Calcium	1.00
Phosphorus	0.73

Production Performance

Final body weight and weight gain were significantly ($p < 0.01$) influenced by treatments (Table 5). Broilers fed Aflasafe maize without ginger (T1) attained the highest final weight (2,450 g). Birds on infested maize without sufficient ginger supplementation (T2) had markedly reduced final weights (1,750 g), reflecting the growth-

Table 3: Ingredients and nutrient composition of broiler starts phase (2-4 weeks) diet (as fed basis)

	Experimental diets				
Ingredients	**T1**	**T2**	**T3**	**T4**	**T5**
Maize	57.00	47.00	42.00	37.00	32.00
Soyabean Meal	20.00	20.00	20.00	20.00	20.00
Ginger Powder	0.00	10.00	15.00	20.00	25.00
Fish Meal	7.50	7.50	7.50	7.50	7.50
Palm oil	3.00	3.00	3.00	3.00	3.00
Limestone	1.00	1.00	1.00	1.00	1.00
Lysine	0.25	0.25	0.25	0.25	0.25
Salt	0.25	0.25	0.25	0.25	0.25
*Premix	0.25	0.25	0.25	0.25	0.25
Methionine	0.25	0.25	0.25	0.25	0.25
P (%)	1.50	1.50	1, 50	1.50	1.50
Total	100.00	100.00	100.00	100.00	100.00
Calculated Analysis					
Crude Protein (%)	22.00	21.50	21.00	20.50	20.00
Crude Fiber (%)	3.50	3.80	4.10	4.40	4.70
EE (%)	7.37	7.37	7.37	7.37	7.37
Calcium (%)	1.10	1.10	1.10	1.10	1.10
Phosphorus (%)	0.50	0.50	0.50	0.50.	0.50
ME (kcal/kg)	3000.02	3000.02	3000.02	3000.02	3000.02
Lysine (%)	1.19	1.19	1.19	1.19	1.19
Meth (%)	0.52	0.52	0.52	0.52	0.52
Ca (%)	1.10	1.10	1.10	1.10	1.10
P %	0.73	0.73	0.73	0.73	0.73

SBM = soya bean meal, Kg = Kilogram, ME = metabolizable energy, CP =crude protein, CF = crude fibre, EE = ether extract, lys = lysine, meth = methionine Ca = calcium, P = phosphorus and (%) = percentage, *Vitamin-Mineral premix (BIOMIX$^{(R)}$) will supply per kg diet; Vit. A 500IU; Vit. D_3 888, IU; Vit. E_{12}, 000mg; Vit. $K_3$15000mg; Niacin 12000mg; Pantothenic acid 2000mg, Biotin 1000mg; Vit b12 3000mg; Folic acid 15000mg; Choline chloride 6000mg, Manganese 1000mg; Vit. Iron 15000mg; Zinc 800mg; Copper 400mg; Iodine 80mg; Cobalt 400mg; Selenium 8000mg.

Table 4: Ingredients and nutrient composition of broiler finisher phase (5-8 weeks) diet (as fed basis).

	Experimental diets				
Ingredients	**T1**	**T2**	**T3**	**T4**	**T5**
Maize	62.00	52.00	47.00	52.00	37.00
Soyabean Meal	15.00	15.00	15.00	15.00	15.00
Ginger Powder	0.00	10.00	15.00	20.00	25.00
Fish Meal	5.00	5.00	5.00	5.00	5.00
Palm oil	5.50	5.50	5.50	5.50	5.50
Limestone	1.00	1.00	1.00	1.00	1.00
Lysine	0.25	0.25	0.25	0.25	0.25
Salt	0.25	0.25	0.25	0.25	0.25
*Premix	0.25	0.25	0.25	0.25	0.25
Methionine	0.25	0.25	0.25	0.25	0.25
P (%)	1.50	1.50	1, 50	1.50	1.50
Total	100.00	100.00	100.00	100.00	100.00
Crude Protein (%)	20.00	19.50	19.00	18.50	18.00
Crude Fiber (%)	3.00	3.30	3.60	3.90	4.20
EE (%)	7.37	7.37	7.37	7.37	7.37
Calcium (%)	1.10	1.10	1.10	1.10	1.10
Phosphorus (%)	0.50	0.50	0.50	0.50.	0.50
ME (kcal/kg)	3000.02	3000.02	3000.02	3000.02	3000.02
Lysine (%)	1.19	1.19	1.19	1.19	1.19
Meth (%)	0.52	0.52	0.52	0.52	0.52
Ca (%)	1.10	1.10	1.10	1.10	1.10
P %	0.73	0.73	0.73	0.73	0.73

SBM = soya bean meal, Kg = Kilogram, ME = metabolizable energy, CP =crude protein, CF = crude fibre, EE = ether extract, lys = lysine, meth = methionine Ca = calcium, P = phosphorus and (%) = percentage, *Vitamin-Mineral premix (BIOMIX$^{(R)}$) will supply per kg diet; Vit. A 500IU; Vit. D_3 888, IU; Vit. E_{12}, 000mg; Vit. $K_3$15000mg; Niacin 12000mg; Pantothenic acid 2000mg, Biotin 1000mg; Vit b12 3000mg; Folic acid 15000mg; Choline chloride 6000mg, Manganese 1000mg; Vit. Iron 15000mg; Zinc 800mg; Copper 400mg; Iodine 80mg; Cobalt 400mg; Selenium 8000mg.

Table 5: Performance of broiler fed graded level of Ginger meal on infested feed contaminated with *Aspergiluus flavus*.

Parameters	T1	T2	T3	T4	T5	SEM	P- value
Initial Weight (g)	45	45	45	45	45	0.5	NS
Final Weight (g)	2.450[a]	1.750[d]	2.300[b]	2.370[b]	2.300[b]	35	<0.01
Total Weight gain (g)	2.405[a]	1.705[d]	2.255[b]	2.325[b]	2.255[b]	32	<0.01
Feed Intake (g)	5.000[b]	4.400[d]	4.900[b]	5.150[a]	5.100[a]	45	<0.05
Feed Conversion Ratio (%)	2.08[b]	2.58[a]	2.17[b]	2.21[b]	2.26[b]	0.05	<0.01
Motility (%)	0	10	2	0	2	-	-

Values in a row with different superscripts (a–d) differ significantly.

Table 6: Serum Biochemical Indices of broiler fed graded level of Ginger meal on infested feed contaminated with *Aspergiluus flavus*.

	Experimental diets						
Parameters	T1	T2	T3	T4	T5	SEM	P- value
ALT (IU/L)	35[c]	72[a]	42[a]	40[b]	42[b]	2.1	<0.01
AST (IU/L)	98[c]	195[a]	110[b]	105[b]	112[b]	4.5	<0.01
Total Protein (g/dL)	6.5[a]	4.5[c]	6.0[ab]	6.2[a]	6.1[ab]	0.2	<0.01
Cholesterol (mg/dL)	150[b]	185[a]	155[b]	152[b]	155[b]	5.2	<0.01

Values in a row with different superscripts (a, b,c and ab) differ significantly.

depressing effects of aflatoxin. Notably, the inclusion of ginger powder at 20% and 30% (T3 and T4) significantly improved body weight gain to 2,300–2.370 g, closely approximating the control. This indicates the capacity of ginger phytochemicals to alleviate aflatoxin-induced growth suppression. Feed intake was highest in T4 (5.150 g) and lowest in T2 (4.400 g), suggesting improved diet palatability and reduced toxicity with higher ginger inclusion. The diets were balanced by reducing maize and replacing with ginger. Adjustments in oil and which is synthetic to amino acids and can be made to maintain energy and protein if needed.

Feed conversion ratio (FCR) was poorest in T2 (2.58) and significantly improved in T3–T4 (2.17–2.21), consistent with improved nutrient utilization as reported by Rashid *et al*. (2020). The highest mortality (10%) was recorded in T2, likely due to the toxic effects of aflatoxin B1, corroborating the findings of Khan *et a*l. (2022), who observed similar mortality trends under aflatoxin challenges. These performance improvements align with Adeyemo *et al*. (2021), who demonstrated that ginger ameliorates growth suppression by reducing oxidative stress and improving gut health.

Hematological Parameters

Hematological indices (Table 6) revealed significant ($p < 0.05$) reductions in packed cell volume (PCV), hemoglobin, and RBC counts in T2. PCV decreased from 36% in T1 to 28% in T2, confirming anemia as a hallmark of chronic aflatoxicosis (Salem *et al*., 2019). Ginger inclusion restored PCV values in T3–T5 (34–35%), approaching the control levels. Similarly, heamoglobin levels improved from 8.9 g/dL in T2 to over 11 g/dL in T3–T5. Elevated leukocyte counts in T2 (30 ×10^3/uL) indicated an inflammatory response, which normalized in T3–T5, suggesting immunomodulatory effects of ginger. These observations were consistent with Nelofer *et al*. (2021), who reported that dietary ginger restored hematological profiles in broilers challenged with mycotoxins.

Serum Biochemical Indices

Serum ALT and AST activities were significantly higher ($p < 0.01$) in T2 (72 and 195 IU/L, respectively), indicating hepatic damage. The inclusion of 15–20% ginger significantly reduced these enzymes (ALT ~40 IU/L, AST ~105 IU/L), supporting the hepatoprotective action of ginger bio-actives. Total serum protein, which decreased under aflatoxin stress (4.5 g/dL in T2), improved in ginger-supplemented treatments (6.0–6.2 g/dL), suggesting improved protein synthesis and liver function. Cholesterol concentrations were highest in T2 (185 mg/dL), reflecting lipid metabolism derangement, while ginger treatments normalized these values, as also described by Majeed *et al*. (2019). These findings were congruent with Ogbe *et a*l. (2022), who highlighted the antioxidative and detoxifying potentials of ginger against aflatoxins.

Bio-economic Indices

Economic evaluation (Table 7) demonstrated that T4 (30% ginger) produced the highest gross margin (₦1,737) and return on investment (38%). While T1 (Aflasafe maize) also yielded high profitability (35% ROI), infested maize with inadequate ginger supplementation (T2) resulted in the lowest ROI (12%), underscoring the significant economic losses caused by aflatoxicosis. Although feed costs increased marginally with higher ginger inclusion, the improved growth performance and survivability offset additional expenses. These outcomes align with Adeyemo *et al*. (2021) and Ogbe *et al*. (2022), who emphasized the economic justification of phytogenic additives in mitigating mycotoxin losses.

Table 7: Bio-economic Indices of broiler fed graded level of Ginger meal on infested feed contaminated with *Aspergiluus flavus*.

	Experimental diets				
Parameters	**T1**	**T2**	**T3**	**T4**	**T5**
Feed Cost/ kg (₦)	200	190	210	215	220
Total Feed Cost per Bird (₦)	1,000	836	1,029	1,107	1,122
Sale Price per Bird (₦)	2,940	2,100	2,760	2,844	2,760
Gross Margin (₦)	1,940	1,264	11,731	1,737	1,638
Return Investment (%)	35	12	32	38	30

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REFERENCES

Adeyemo, G. O., Abioye, O. S., & Adebiyi, O. A. (2021). Use of ginger and turmeric as phytogenic additives to mitigate mycotoxin effects in poultry. *Poultry Science Journal*, 59(3), 205–215.

Ari, M.M., Hassan, D. I., Yakubu, A., & Adua, M. M. (2020). Preliminary Screening of Some Nutraceuticals as Aflatoxin (*Aspergillus flavus*) Reduction Agents Using *In Vitro* growth Inhibition Technique. *International Journal of Innovative Science and Research Technology*. Volume 5, Issue 7, ISSN No:-2456-2165.

Bernard, F. F., Josephand, G. Z., & Jain, N. C. (2000). Schalm's Veterinary Hematology. 5th Ed. Lippincott Williems and Wilkin, Philadelphia. Pp.36.

Chilaka, C. A., De Boevre, M., Atanda, O. O., & De Saeger, S. (2020). Surveillance of aflatoxin and fumonisin in Nigerian maize: Current status and future perspectives. *World Mycotoxin Journal, 13*(3), 241–255. https://doi.org/10.3920/WMJ2019.2477

Chinwe, I. F., Chinedu, N. S., & Emeka, E. A. (2012). *Effects of aflatoxin-contaminated maize grains on growth performance and hematological parameters of broiler chicks. International Journal of Poultry Science*, 11(8), 529–535.

Coles, E. H. (1986). Veterinary Clinical Pathology 4th Edition, W. B. Saunders. Philadelphia. Concentrations of malunggay (*Moringa oleifera* lam.) aqueous leaf extract. Online *Journal of Animal and Feed Research*. **2**, Issue 6: 465-469 ISSN 2228-7701.

Duncan, D. B. (1955) multiple ranges and multiple F- test. Biometrics **11**, 1-42.

Ezekiel, C. N., Oyedele, O. A., Kaptchouang Tchana, A. N., & Bandyopadhyay, R. (2021). Mycotoxin exposure in sub-Saharan Africa: A review of recent studies. *Food Control, 123*, 107737. https://doi.org/10.1016/j.foodcont.2020.107737

FAO. (2020). Mycotoxin management in agriculture: A training manual for agricultural extension workers in Africa. Food and Agriculture Organization of the United Nations. http://www.fao.org/publications

Food and Agriculture Organization (F.A.O). Worldwide Regulations for Mycotoxins in Food and Feed in 2003:F.A.O Food and Nutrition Paper 81. Rome. Pp. 54-68.

Hassan, D. I., Aya, V. E., Alaku, A. I., Musa, S. I., Barde, R. E., Adua, M. M., & N. D. Yusuf. (2015). Effects of *Moringa oleifera* leaves on Body weight and Haematological parameters of Rabbits infected with *Trypanasoma congolence. PAT.**11** (2): 253-259 ISSN: 0794-5213. www.patnsukjournal.net/currentissue*

Khan, M. Z., Saleemi, M. K., & Khan, A. (2022). Natural strategies for aflatoxin detoxification in poultry feed: a review. *World's Poultry Science Journal*, 78(1), 1–16.

Kolawole, O., Meneely, J., Greer, B., & Elliott, C. T. (2022). A review of mycotoxin mitigation strategies: Implications for sub-Saharan Africa. *Toxins, 14*(1), 15. https://doi.org/10.3390/toxins14010015

Kos, G., & Krska, R (2003). *Training Course 2: Separation and detection techniques for the determination of mycotoxins*, European Mycotoxin Awareness Network, viewed 3 April 2014, <http://services.leatherheadfood.com/eman/FactSheet.aspx?ID=62>.

Lewis, W. H. (1991). *Mycotoxins and their effect on animal health. Journal of Animal Science*, 69 (Suppl. 2), 164–169.

Majeed, S., Mushtaq, A., & Javed, M. T. (2019). Role of phytogenic feed additives in poultry health management. *Journal of Applied Poultry Research*, 28(1), 1–12.

Misihairabgwi, J. M., Ezekiel, C. N., Sulyok, M., & Krska, R. (2022). Mycotoxins in African food and feed: Trends and perspectives for improving food safety. *Critical Reviews in Food Science and Nutrition, 62*(8), 2080–2093. https://doi.org/10.1080/10408398.2020.1847134

National Research Council (N.R.C) (1996). Nutrient Requirements of Poultry. 10th (Eds), National Academy Press, Washington, DC.

Nelofer, R., Qureshi, S., & Yasmeen, S. (2021). Herbal feed additives as aflatoxin binders in poultry: A review. *International Journal of Veterinary Science*, 10(1), 15–24.

NIMET (2012). Nigerian Metrological Agency Lafia, Nasarawa state.

Ogbe, A. O., Atawodi, S. E., & Abdu, P. A. (2022). Economics of aflatoxin detoxification strategies in maize-based diets for broiler chickens. *Tropical Animal Health and Production*, 54(2), 1–12.

Okoth, S. A. (2021). Strategies to mitigate aflatoxin contamination in Africa: A review. *African Journal of Food, Agriculture, Nutrition and Development, 21*(2), 17680–17699. https://doi.org/10.18697/ajfand.98.20409

Oluduro, A. O. (2012). Evaluation of antimicrobial properties and nutritional potentials of *Moringa oleifera* Lam. leaf in South Western Nigeria, *Malaysian Journal of Microbiology*, **8** (2): 59-67.

Oluyemi, J. A., & Robert, F. A. (2002). Poultry production in warm wet climates, 2nd edition, published by Macmillan publishers limited, London.pp.45-77.

Platel, K., & Srinivasan, K (1996) Influence of dietary spices of their active principles on digestive enzymes of small intestinal mucosa in rats. *Int. J. Food Sci. Nutr.* **47**: 55 -59.

Rashid, M., Ali, M., & Khan, N. (2020). Antioxidative and hepatoprotective properties of ginger against aflatoxin B^1 toxicity in broilers. *Journal of Animal Physiology and Animal Nutrition*, 104(3), 658–665.

Salem, M. E., El-Maaty, H. M., & Hassan, R. A. (2019). Mitigation of aflatoxin residues in poultry feed using herbal supplements. *Animal Feed Science and Technology*, 252, 1–10.

Shipra, V., Ghosh, R. C., Mukherjee, R.**, &** Pande, V. V. (2012). *Evaluation of ameliorative effects of herbal preparation in experimentally induced aflatoxicosis in broiler chickens. Indian Journal of Veterinary Pathology***, 36(1), 7–12.**

Statistical Package for Social Science (SPSS). (2012) 20.0 Brief Guide: SPSS Inc. 233.

Steel, R. G. D. , & Torrie, J. H. (1980) principles and procedures of statistics 2 nd Ed. Mcgraw, Hill New York, U. S. A. 633pp.

Udom, I. E., Okon, A. E. and Udoh, A. R. (2023). Dietary aflatoxin exposure and immunotoxicity in poultry: Mechanisms and mitigation. *Poultry Science, 102*(5), 102608. https://doi.org/10.1016/j.psj.2023.102608

Wu, Q., Wang, X., Yang, W., Nüssler, A. K., & Xiong, L. (2023). Biodegradation of aflatoxins in feed: Advances, limitations and prospects. *Toxicon: X, 17*, 100131. https://doi.org/10.1016/j.toxcx.2023.100131.