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An overview of mycotoxins in poultry health

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Abstract: Mycotoxins are toxic by-products produced by certain molds comprising mainly species from *Aspergillus*, *Fusarium*, and *Penicillium spp.*, that often show up in poultry feed and put birds at serious risk. When chickens or other poultry get exposed to these toxins (e.g., aflatoxins in some cases), it weakens their immune defenses, cuts down on how efficiently they turn feed into growth, causes damage to organs, and leaves them far more open to picking up infections. In the end, this drags down overall flock performance and makes sustainable poultry farming tougher to achieve.

To fight back against these problems, people have come up with and put into practice a range of approaches, including biological ones, chemical treatments, and physical methods. Among them, a practical and widely used option involves adding adsorbents (or mycotoxin binders) right into the feed. Common ones include zeolite, bentonite, yeast cell wall products, and activated charcoal. These work by trapping the toxins in the birds' digestive system, so they're less likely to get absorbed into the body. Non-nutritive feed additives (enzyme-based detoxifiers and probiotics) are effective biological approaches for breaking down mycotoxins. Proper feed storage and application of antifungal agents all play a crucial role in reducing fungal contamination.

Keywords: mycotoxin; strategies; binders; poultry health; immunosuppression

INTRODUCTION

In poultry nutrition, mycotoxins negatively impact feed quality and nutrient absorption thereby leading to poor growth performance, reduced feed efficiency, they are toxic compounds produced by fungi, especially molds, which can contaminate agricultural commodities and feed-stuffs. These secondary metabolites are predominantly produced by species of the genera *Aspergillus*, *Penicillium*, and *Fusarium spp.* Mycotoxins pose significant risks to animal health, and poultry are particularly vulnerable due to their diet, which often includes grains such as corn, wheat, and barley foods prone to fungal contamination (Chelenga et al., 2025). Mycotoxins in poultry feed affect chicken health and growth and also contaminate their eggs and meat (Castaldo and Vurro, 2017). Saqer (2013) reported that

aflatoxin residues were present in eggs, muscles (legs, breast), organs (liver, kidneys and gizzards) and litter in noticeable amounts.

As production of food increases globally, maintaining a high degree of vigilance and readiness against mycotoxin contamination in poultry feeds is imperative. The involvement of veterinarians, nutritionists, and farmers in actively monitoring and controlling these hazards has never been more vital to protecting poultry health and ensuring a safe, sustainable food supply (Nakavuma et al., 2020). Chicken feed mainly consists of grain seeds, soybeans, grass, biscuits, meat, blood, fish meal, fat, oil, decorticated cottonseed bran, corn gluten bran, guar bran, peanut cake minerals and sub therapeutic antibiotics which may be contaminated with soil toxins, fungi and parasites (Suleman et al., 2022). In the poultry industry, the presence of mycotoxins in feed can result

in a range of detrimental effects on bird health, growth, productivity, and immune function. Even low levels of mycotoxin contamination in poultry feed can cause chronic issues with growth, production, and immune function and in some cases, acute toxicity leading to high mortality rates (Suleman et al., 2022).

This review paper will assess the impact of mycotoxin contamination on poultry health and mitigation strategies.

MYCOTOXINS

Mycotoxin originates from the Greek word “mykes” (meaning fungus or mold) and the Greek/Latin-derived “toxicon” (meaning poison or toxic) (Murugesan et al., 2015). Mycotoxins are secondary metabolites, produced by filamentous fungi as coping strategies under environmental pressure and functioning as fitness factors to enhance pathogenicity, aggressiveness and/or virulence of fungi (Venkatesh and Keller, 2019; Ran, 2023). There are 200 key mould examples that can severely affect poultry health and performance, including aflatoxins (AFs), zearalenone (ZEN), ochratoxin A (OTA), fumonisins (FUM), and trichothecenes such as deoxynivalenol (DON) and T-2 toxin (Murugesan et al., 2015).

Mycotoxins are among the most significant hazards to feed supply chain and pose a threat to feed industries worldwide with a direct impact on feed safety, animal health and productivity, public health via animal by-products, economies and international trade (Antonissen et al., 2014; Wu, 2015; Brennan et al., 2017; Santos et al., 2019; Brown et al., 2021). These toxic compounds are commonly detected as natural contaminants in a variety of agricultural commodities of plant origin, especially in cereal grains, and are therefore often detected in animal feeds containing corn, soybean, and wheat (Smith et al., 2016; Alshannaq and Yu, 2017; Santos et al., 2019), but can also be present in silage, haylage and pasture (Reisinger et al., 2019; Andersen et al., 2020; Penagos-Tabares et al., 2021). Major mycotoxins can also be found in animal-derived products such

as eggs, meat, milk and milk by-products with varying residual concentrations due to carry-over from animals that have consumed contaminated feeds.

TYPES OF MYCOTOXINS AFFECTING POULTRY

Several types of mycotoxins (as shown in Fig. 1) are of particular concern in poultry farming due to their toxicological effects. The overview of mycotoxins highlighting their effects, producing fungi etc. is shown in Table 1, while Table 2 shows the occurrence levels of these mycotoxins in Nigerian feed. The most common mycotoxins affecting poultry health include:

1. AFs

Aflatoxins are among the most well-known and studied mycotoxins. They are primarily produced by *Aspergillus flavus* and *Aspergillus parasiticus* (Alshannaq and Yu, 2017; Maurya, 2025). Aflatoxins are potent carcinogens and are capable of causing significant damage to the liver, immune system, and overall metabolism of poultry (Suleman et al., 2022).

a. Impact on poultry: Aflatoxins primarily affect the liver by inducing oxidative stress, inflammation, and cellular damage. This can lead to hepatotoxicity, cirrhosis, and, in some cases, liver cancer (Mekuria et al., 2020; Hua et al., 2021; Fan et al., 2023).

b. Symptoms: Anorexia, stunted growth performance, icterus, immunosuppression, and elevated mortality rates (Hua et al., 2021).

c. Thresholds: “In poultry, subclinical manifestations can arise from aflatoxin exposure at concentrations as low as 20 ppb, whereas dietary levels exceeding 100 ppb frequently induce acute aflatoxicosis, characterized by severe clinical signs and elevated mortality (Lin et al., 2014; Hua et al., 2021).

2. OTs

Ochratoxins are produced by *Aspergillus ochraceus* and *Penicillium verrucosum* and can contaminate grains like barley and wheat. Ochra-

Table 1. Overview of the mycotoxins

Mycotoxin	Producing fungi	Primary effects on poultry	EU Guidance/ threshold (ppb) in poultry feed	Global prevalence (recent data, 2024 - 2025)
Aflatoxins (AFB1 dominant)	<i>Aspergillus flavus</i> , <i>A. parasiticus</i>	Hepatotoxicity, immunosuppression, reduced growth, mortality	20 (complete feed)	4 - 20 % exceeding risk thresholds; rising in 2025
Ochratoxin A (OTA)	<i>Aspergillus ochraceus</i> , <i>Penicillium verrucosum</i>	Nephrotoxicity, kidney damage, immunosuppression	100 - 250 (guidance)	5 - 15 % above thresholds
Fumonisin (FB1/FB2)	<i>Fusarium verticillioides</i> , <i>F. proliferatum</i>	Liver/lung damage, poor growth, sphingolipid disruption	5.000 - 20.000 (guidance)	50 - 70 % prevalence; high in maize-based feeds
Zearalenone (ZEN)	<i>Fusarium graminearum</i>	Estrogenic effects, reproductive issues, reduced egg production	250 (guidance)	39 - 60 % prevalence; increasing in 2025
Deoxynivalenol (DON) / Trichothecenes (e.g., T-2)	<i>Fusarium spp.</i>	GI lesions, immunosuppression, vomiting, reduced feed intake	1.000 - 5.000 (guidance for DON); T-2/HT-2: 250 - 500	DON: 70 - 85 %; T-2: variable, often co-occurring
Emerging (e.g., Enniatins, Beauvericin)	<i>Fusarium spp.</i>	Immunosuppression, gut disruption (synergistic with others)	Not regulated yet	20 - 40 % in co-contaminated samples

Source: EU Commission Recommendation 2006/576/EC

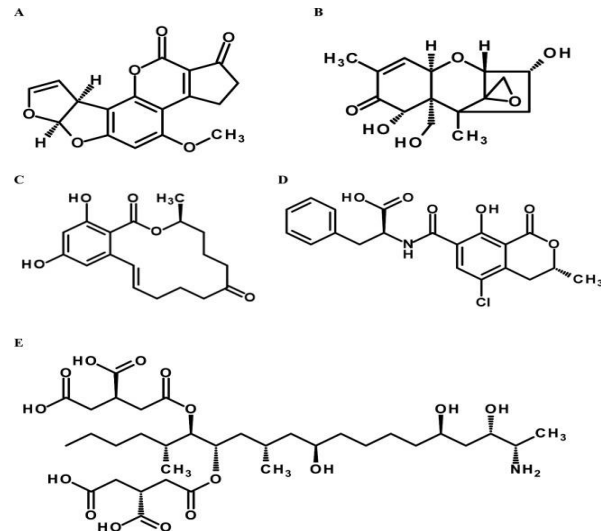


Figure 1. Chemical structures of most prevalent mycotoxins.

A: Aflatoxin B₁, B: Deoxynivalenol, C: Zearalenone, D: Ochratoxin A, E: Fumonisin B₁

Source: Murugesan et al. (2015)

Table 2. Occurrence level in Nigerian poultry feed

Metabolites	Incidence of contamination (%)
Aflatoxin B1	83.3
Aflatoxin B2	50.0
Aflatoxin G1	56.7
Aflatoxin G2	13.3
Aflatoxin M1	23.3
Deoxynivalenol	20.0
Fumonisin B1 (FB1)	96.7
Fumonisin B2	93.3
Fumonisin B3	90.0
Fumonisin B4	96.7
Ochratoxin A	26.7
Ochratoxin B	20.0
Tenuazonic acid	70.0
Zearalenone (ZEN)	83.3
ZEN-sulfate	13.3

Source: Akinmusire et al. (2018)

toxins are nephrotoxic (toxic to the kidneys) and have been shown to cause immunosuppression in poultry (Agriopoulou et al., 2020).

a. Impact on poultry: Ochratoxins primarily affect the kidneys, causing kidney enlargement, reduced renal function, and metabolic disturbances. They also have immunosuppressive effects, which make poultry more susceptible to infections (Agriopoulou et al., 2020).

b. Symptoms: Reduced feed intake, growth retardation, kidney damage, and increased susceptibility to secondary infections (Agriopoulou et al., 2020).

c. Thresholds: 0.2-0.5 mg/kg (Bonerba et al., 2024).

3. FUM

Fumonisin are produced by *Fusarium* species. There are six FUM (A_1 , A_2 , B_1 , B_2 , B_3 , B_4) *Fusarium verticillioides* and *Fusarium proliferatum* are commonly found in corn. An example of *Fusarium* growth is shown in Figure 2. Chickens and turkeys are relatively resistant to the toxic effects of FB_1 (Murugesan et al., 2015). Fumonisin have been linked to a range of health problems in poultry, including liver

damage, lung edema, and neurological disorders (Bracarense et al., 2012).

a. Impact on poultry: Fumonisin interfere with sphingolipid metabolism in poultry, leading to organ toxicity, especially in the liver and lungs. They are also associated with poor growth performance and immune suppression.

b. Symptoms: Respiratory distress, poor weight gain, liver and lung damage, and reduced egg production.

4. ZEN

Zearalenone is produced by *Fusarium* species, especially *Fusarium graminearum*, and commonly contaminates corn and wheat. Zearalenone is estrogenic and can cause hormonal imbalances in poultry (Bracarense et al., 2012).

a. Impact on poultry: Zearalenone mimics estrogen, which can disrupt normal reproductive function in poultry, especially in laying hens. It can lead to reduced egg production, abnormal egg formation, and reproductive disorders (Foerster et al., 2023).

b. Symptoms: Enlarged ovaries, reduced fertility, abnormal egg shells, and decreased hatchability (Molapo and Motselsi, 2020).



Figure 2. Growth of *Fusarium* on maize

Source: Grahame (2021)

5. T-2 toxin

Trichothecene mycotoxins, notably T-2 toxin, are secondary metabolites synthesized by multiple *Fusarium* species. These compounds exhibit high potency and exert profound toxic effects in poultry, with pronounced impacts on the immune system (leading to immunosuppression), and the gastrointestinal tract (including mucosal necrosis and lesions) (Adhikari et al., 2017).

i. Impact on poultry: Pronounced inflammatory responses, immunosuppression, and gastrointestinal mucosal lesions. Protein synthesis inhibition in cells, leading to widespread cytotoxic damage (Adhikari et al., 2017).

ii. Symptoms: Vomiting, diarrhea, immune suppression, lesions in the gastrointestinal tract, and reduced growth performance (Adhikari et al., 2017).

MECHANISM AND EFFECT OF MYCOTOXINS ON POULTRY HEALTH

Mycotoxins have far-reaching effects on poultry health, affecting multiple organ systems and physiological processes. The following outlines the primary impacts:

1. Liver damage and hepatotoxicity

Aflatoxins and ochratoxins preferentially induce severe liver pathology in avian species. The liver, responsible for metabolizing and eliminating foreign toxins, becomes saturated and damaged upon mycotoxin exposure through CYP450-dependent activation and subsequent oxidative/cytotoxic cascades thereby leading to disrupted hepatic function. This manifests as diminished nutrient biotransformation and utilization, contributing to clinical malnutrition, stunted growth, and, at higher doses, acute or subacute liver failure (Suleman et al., 2022).

a. Mechanism: Mycotoxins promote oxidative imbalance by inducing ROS overproduction, resulting in peroxidation of polyunsaturated fatty acids within hepatocyte membranes and subsequent loss of membrane integrity. This process drives necrotic cell death (hepatocellular necrosis) and elicits local inflammation in hepatic tissue (Moloi et al., 2024).

b. Consequences: According to Suleman et al. (2022), hepatotoxicity impairs hepatic protein synthesis, compromises the liver's capacity for vitamin storage and activation, and contributes to a generalized deterioration in avian health and performance.

2. Immunosuppression

Immunosuppression is a critical effect of mycotoxin exposure that impair immune function, leading to susceptibility of poultry to infectious diseases. Mycotoxin-mediated immunosuppression impairs vaccine efficacy in poultry by suppressing key immune mechanisms, including reduced antibody production, diminished lymphocyte proliferation, and weakened humoral and cell-mediated responses following immunization (Pierron et al., 2016).

a) Mechanism: Mycotoxins interfere with immune cell function, including the production of antibodies and the activity of macrophages and lymphocytes (Olariu et al., 2025).

b) Consequences: This increases the susceptibility of poultry to infections, leading to higher mortality rates and slower recovery from illness (Olariu et al., 2025).

3. Reduced growth and productivity

Mycotoxins can significantly impair growth, feed conversion efficiency, and overall productivity. Reduced feed intake due to gastrointestinal discomfort, combined with the metabolic disruptions caused by toxins, can lead to stunted growth in poultry.

Mechanism: Toxins, such as AFs and FUM reduce feed intake by causing gastrointestinal irritation and impacting nutrient absorption. Growth hormone production may also be disrupted (Bracarense et al., 2012).

Consequences: Lower body weight, poor feed conversion, and reduced egg production lead to economic losses for poultry producers (Bracarense et al., 2012).

4. Reproductive issues

Mycotoxins like zearalenone have estrogenic properties, which can cause reproductive dysfunc-

tion in poultry. In laying hens, zearalenone exposure can lead to hormonal imbalances that impair egg production and fertility (Wu et al., 2021).

- a. Mechanism: ZEN mimics estrogen, causing the enlargement of reproductive organs and altered egg formation (Yuan et al., 2022).
- b. Consequences: Reduced egg production, infertility, and abnormal egg characteristics (e.g., soft-shelled eggs) (Yuan et al., 2022).

5. *Gastrointestinal and neurological damage*

Some mycotoxins, especially trichothecenes like T-2 toxin, can cause severe gastrointestinal lesions, including inflammation, bleeding, and ulceration. Additionally, T-2 toxin can cause neurological symptoms such as tremors, ataxia, and convulsions (Suleman et al., 2022).

- a. Mechanism: Trichothecenes inhibit protein synthesis and cause direct cellular damage to the gastrointestinal and nervous systems (Suleman et al., 2022).
- b. Consequences: Impaired nutrient absorption, weight loss, and neurological impairments.

DIAGNOSIS AND DETECTION OF MYCOTOXINS IN POULTRY

Accurate and early diagnosis of mycotoxins is crucial for effective management. Mycotoxins can be detected in both feed and biological samples using the following methods:

1. *Chromatographic methods*

- a. High-Performance Liquid Chromatography (HPLC): A highly accurate method for quantifying specific mycotoxins in feed samples.

- b. Gas Chromatography-Mass Spectrometry (GC-MS): Used for detailed analysis of volatile and semi-volatile mycotoxins.

2. *Immunoassays*

- i. Enzyme-Linked Immunosorbent Assay (ELISA): A commonly used, cost-effective test to detect mycotoxins in feed and poultry products.

3. *Spectrophotometric methods*

These methods involve the measurement of absorbance spectra of specific mycotoxins, and can be applied for rapid screening.

POSITIVE EFFECTS OF FUNGI ON POULTRY HEALTH

1. *Probiotics and feed additives*

Fungi like yeast (*Saccharomyces cerevisiae*) can be used as probiotic feed additives to improve gut health and nutrient absorption and reduce pathogenic bacteria in the gut.

2. *Enzyme production*

Fungi are used to produce enzymes (xylanases, phytases), and added to poultry feed to improve feed digestibility by breaking down complex carbohydrates and increase the availability of nutrients, e.g., phosphorus (Kayan et al., 2025).

PREVENTIVE, DIAGNOSTIC, AND MITIGATION STRATEGIES

Advanced mitigation technologies for mycotoxins in poultry feed are evolving rapidly, leveraging nanotechnology, enzyme engineering, and artificial intelligence (AI), to enhance detoxifi-

Table 3. Mitigation strategies comparison (examples and suitability)

Strategy category	Examples	Suitability to poultry feed
Preventive	Proper drying, storage, resistant crops, early harvest	High (first line)
Physical	Sorting, washing, irradiation, heating	Medium (post-harvest)
Chemical	Oxidizing agents (e.g., ozone, ammonia)	Low–Medium
Biological	Enzymes (e.g., FumD for FBs, ZenA for ZEN), probiotics, microbes	High (emerging)
Adsorbent/Binder	Bentonite, zeolite, activated charcoal, yeast cell walls	High (widely used)
Advanced/Nano	Nano-adsorbents, NP-functionalized binders	Emerging

Source: Authors' own elaboration

cation efficiency and precision. The mitigation strategy is shown in Table 3.

1. Integrated management practices

Preventing fungal contamination at the farm level is the first line of defense. This includes proper storage, drying, and handling of grains, early-matured seeds, smart agricultural practices, early harvesting, good post-harvest practices to minimize fungal growth (Vila-Donat et al., 2018; Hua et al., 2021).

i. Mycotoxin binders

Feed additives such as clay minerals (bentonite, biochar and zeolite) can adsorb mycotoxins, reducing their bioavailability and toxicity in animal feed.

ii. Regular surveillance

Regular screening of feedstuffs and poultry products for mycotoxin contamination is essential to minimize risks. Early detection enables prompt intervention.

iii. Detoxification strategies

Research into biological and enzymatic detoxification methods is ongoing. Certain microbes and enzymes can degrade or modify mycotoxins to reduce their toxicity (Castaldo and Vurro, 2017). Enzyme-based detoxifiers, (fumonisin esterase FumD and zearalenone lactonase ZenA), target specific prevalent mycotoxins, outperforming broad-spectrum binders in multi-contaminated feeds (Mateo et al., 2025). Plant-derived NPs (thyme, garlic, and ginger) boost growth and gut health as antibiotic alternatives (Mateo et al., 2025).

iv. Decontamination methods

Decontamination of mycotoxin include chemical methods (such as oxidation, alkalization, hydrolysis, reduction, conjugation, and hydration) and physical methods (such as cleaning and sorting, dehulling milling, adsorption, heating, irradiation, ultrasound, and pulsed light) (Peng et al., 2018; Ding et al 2022; Bonerba et al., 2024).

v. Regulatory perspective

European Commission (2006) established a new group of technological feed additives for the reduction of mycotoxins in feed. In 2010, the European Food Safety Authority (EFSA) published guidelines with stringent requirements:

vi. The binding capacity must be demonstrated;

vii. Mycotoxin degradation products must be safe for target animals and consumers;

viii. Minimum 3 in vivo studies with significant efficacy at the lowest recommended dose;

ix. Relevant biomarkers of each individual mycotoxin have to be used to demonstrate the efficacy of the product, for the evaluation of mycotoxin deactivating products (EFSA, 2010).

KEY PREVALENCE (NIGERIA SURVEY)

i. A 2023 - 2024 study in Oyo State (158 poultry feed/ingredient samples) found AFs and FUM above permissible limits in 32.9 % and 18.4 % of dry-season samples, respectively. Every sample contained at least four mycotoxins; AFs + FBs co-occurred in 80 %. Wet-season contamination was lower, but still widespread (Esan et al., 2024).

ii. In Jos and Kaduna feed mills (2025 study), total AFs exceeded the 20 µg/kg WHO/FAO limit in many broiler starter/finisher feeds (means 14 - 22 µg/kg; max up to 51 µg/kg). Moisture correlated positively with AF levels ($r = 0.92$), linking poor storage to risks (Daramola and Omokpariola, 2025).

iii. Earlier but influential data (2018 - 2021 reviews) show fumonisin B1 in 97 % of feeds (mean ~1014 µg/kg), AFs in 83% (mean 74 µg/kg for AFB1), with peanut cake as a hotspot (Akinmusire et al., 2018).

CONCLUSION

Mycotoxins represent a major challenge for the poultry industry, impacting animal health, production, and overall welfare. The variety of mycotoxins such as AFs, OCT, FUM, ZEN, and

T-2 toxin pose different threats to poultry, including liver damage, immune suppression, reduced reproductive success, and growth retardation which depend on the level and duration of exposure, with low levels causing subclinical damage that may not be immediately obvious but can reduce the overall performance of the birds.

RECOMMENDATIONS

Due to the wide range of detrimental effects, the following can be recommended:

a. Prevention of fungal contamination through proper agricultural practices (planting of resistant varieties, early harvesting and post-harvest handling), using mycotoxin binders in feed, and regularly monitoring feed and poultry products are essential steps to minimize exposure.

b. Advances in mycotoxin detection and detoxification techniques, such as routine screening to mitigate the impact of mycotoxins on poultry health, thereby ensuring the sustainability and profitability of poultry production.

c. Continued research to better understand the mechanisms of mycotoxin toxicity, improve diagnostic methods, and develop more effective mitigation strategies.

d. Enforcement of maximum permissible levels in grains to safeguard poultry and public health.

Conflict of interest

The authors declare no conflict of interest.

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