

# Mycotoxicosis in pigeons: feed contamination, clinical impact, and mitigation

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**Abstract.** Mycotoxicosis in pigeons (*Columba livia*) represents an underexplored but potentially significant health constraint associated with the ingestion of contaminated cereal-based feeds. This mini-review synthesizes current knowledge on the occurrence, sources, biological effects, and mitigation strategies of major mycotoxins relevant to pigeon nutrition, including deoxynivalenol (DON), zearalenone, fumonisins, aflatoxins, ochratoxin A, and emerging mycotoxins. Feed contamination is shown to be widespread and frequently characterized by multi-mycotoxin co-occurrence, even in commercial or apparently safe formulations. Although specific experimental data in pigeons remain limited, extrapolation from poultry and swine indicates that chronic low-dose exposure leads to impaired growth, immune dysregulation, altered gut integrity, and increased susceptibility to infectious diseases. Experimental evidence in pigeons exposed to DON further demonstrates effects on intestinal physiology and pathogen shedding, despite limited overt clinical signs. Mechanistically, mycotoxins act primarily through oxidative stress, inhibition of protein synthesis, disruption of intestinal barrier function, and immune modulation, with additive or synergistic effects in multi-contaminant scenarios. Mitigation strategies include improved feed hygiene, storage control, analytical monitoring, and the use of adsorbents and biotransforming feed additives. This review highlights the need for pigeon-specific toxicological research and integrated feed safety strategies within a One Health framework.

**Key Words:** aflatoxins, deoxynivalenol, feed additives, feed contamination, fumonisins, intestinal health, mycotoxicosis, ochratoxin A, pigeons, zearalenone.

**Introduction.** Pigeons (*Columba livia*) constitute an essential model organism in biological research, as their exceptional navigational performance, phenotypic diversity, and thoroughly characterized physiology allow for integrative analyses of behavior, morphology, and metabolism (Ionescu & Oroian 2015; Ionescu et al 2015; Ionescu & Oroian 2019; Popescu & Cimpean 2026; Popescu et al 2026).

Mycotoxicosis in pigeons is largely linked to contamination of cereal-based feeds by fungal secondary metabolites such as deoxynivalenol (DON) and other *Fusarium*, *Aspergillus*, and *Penicillium* toxins (Bryden 2012; Antonissen et al 2016; Pinotti et al 2016; Magnoli et al 2019; Yang et al 2020; Akinmoladun et al 2025). Although direct pigeon data are scarce, extensive work in poultry and pigs shows that chronic low-level exposure impairs performance, immunity, and disease resistance, making feed contamination in pigeons a genuinely underexplored but high-risk niche (Murugesan et al 2015; Antonissen et al 2016; Kolawole et al 2024; Olariu et al 2025; Akinmoladun et al 2025).

The aim of this mini-review is to provide a comprehensive synthesis of current knowledge regarding mycotoxicosis in pigeons, with a focus on feed contamination, pathophysiological effects, and mitigation strategies. Specifically, the study seeks to (i) identify the major mycotoxins and contamination patterns present in cereal-based pigeon feeds, (ii) evaluate their biological and clinical impacts on intestinal health, immune function, and performance based on available pigeon data and extrapolated evidence from poultry and swine, and (iii) assess current and emerging mitigation strategies, including

feed management practices and detoxifying feed additives. Additionally, the review aims to highlight critical knowledge gaps and the need for species-specific research to better understand the impact of chronic, low-level, multi-mycotoxin exposure in pigeons.

**Sources and Patterns of Mycotoxin Contamination in Pigeon Feed.** Seed-based racing pigeon diets (maize, wheat, barley and other cereals) are frequently contaminated with DON; in one survey, DON was detected in 5 of 10 commercial seed-based feeds ( $177\text{--}1466\ \mu\text{g kg}^{-1}$ ) (Antonissen et al 2016). Multi-mycotoxin LC MS/MS analysis of a nominal “control” pigeon feed still found low levels of several toxins (DON, 3 and 15 acetyl-DON, zearalenone, fumonisins), illustrating that multi-contamination at subclinical levels is common even in apparently safe rations (Antonissen et al 2016). Broader feed-chain data confirm that 76–81% of global grain/feed samples contain at least one mycotoxin and that co-occurrence of DON, zearalenone, fumonisins, aflatoxins, ochratoxin A and emerging toxins is the rule rather than the exception (Bryden 2012; Murugesan et al 2015; Pinotti et al 2016; Magnoli et al 2019; Kolawole et al 2024; Akinmoladun et al 2025). Cereal by products from milling, ethanol, and brewing processes tend to concentrate mycotoxins and are widely used in animal feeds, potentially increasing exposure where such by-products are used in pigeon formulations (Pinotti et al 2016; Čolović et al 2019). Climate, storage conditions and processing practices all modulate fungal growth and toxin formation along the feed supply chain (Bryden 2012; Pinotti et al 2016; Dey et al 2022; Gómez-Osorio et al 2024; Akinmoladun et al 2025).

**Clinical and Subclinical Effects in Pigeons and Extrapolation from Other Species.**

In pigeons experimentally fed DON-contaminated extruded pellets ( $\sim 3538\ \mu\text{g kg}^{-1}$ ), oral bioavailability of DON was low ( $F\approx 30\%$ ), but intestinal epithelial cells were exposed to substantial luminal DON, leading to altered host–pathogen interactions with *Salmonella* (Antonissen et al 2016). DON feeding significantly increased the proportion of birds shedding *Salmonella* ( $87\pm 17\%$  vs  $74\pm 13\%$  in controls), suggesting facilitation of bacterial spread, although overt clinical disease, organ lesions, and organ *Salmonella* loads were not worsened (Antonissen et al 2016). Semi-quantitative high-resolution mass spectrometry identified DON 3 $\alpha$  sulfate as the major metabolite in pigeons, after both intravenous and oral administration, indicating species-specific detoxification but persistent local intestinal effects (Antonissen et al 2016).

Data from poultry show that aflatoxins, trichothecenes (including DON), fumonisins, ochratoxin A, and zearalenone impair growth, feed conversion, organ integrity (liver, kidney, gut), and especially immune responses, decreasing vaccine efficacy and increasing susceptibility to coccidiosis, salmonellosis and viral diseases (Murugesan et al 2015; Pierron et al 2016; Xu et al 2022; Kolawole et al 2024; Gómez-Osorio et al 2024; Okasha et al 2024; Olariu et al 2025). In pigs, similar toxins disrupt intestinal barrier function, alter microbiota, and cause immunosuppression or dysregulated immune activation, leading to higher infection rates and poorer vaccine responses (Pierron et al 2016; Yang et al 2020; Holanda & Kim 2021; Recharla et al 2022; Hung et al 2024; Raj et al 2025). It is therefore plausible, though not yet systematically documented, that racing pigeons exposed to comparable multi-mycotoxin patterns may exhibit reduced performance, impaired gut health, and increased infectious disease burden at exposure levels below those causing overt mycotoxicosis (Table 1).

Experimental and field studies across species emphasize that chronic, low-dose multi-mycotoxin exposure leads to reduced feed intake, poor weight gain, lower egg output, decreased fertility and hatchability, and increased disease susceptibility, often without clear, specific clinical signs (Bryden 2012; Murugesan et al 2015; Pierron et al 2016; Magnoli et al 2019; Recharla et al 2022; Gómez-Osorio et al 2024; Hung et al 2024; Akinmoladun et al 2025). This pattern fits the likely situation in pigeons routinely consuming contaminated seed mixes.

Table 1

Major mycotoxins, sources, and effects relevant to pigeon-type diets

<i>Mycotoxin / Group</i>	<i>Main feed sources and co-contaminants</i>	<i>Principal biological effects in food animals (esp. birds, pigs)</i>	<i>References</i>
Deoxynivalenol (DON)	Fusarium-contaminated cereals and seed-based pigeon feed; often with ZEN, FBs	Anorexia, reduced growth, gut epithelial damage, altered permeability, immune modulation, increased pathogen shedding; DON 3 $\alpha$ sulfate major metabolite in pigeons	Murugesan et al 2015; Antonissen et al 2016; Pierron et al 2016; Yang et al 2020; Holanda & Kim 2021; Recharla et al 2022; Xu et al 2022; Kolawole et al 2024
Zearalenone (ZEN)	Maize and cereal by products, frequently with DON, FBs	Estrogenic effects, reproductive disorders, possible co toxic effects on gut and immunity	Murugesan et al 2015; Pinotti et al 2016; Holanda & Kim 2021; Recharla et al 2022; Xu et al 2022; Hung et al 2024; Akinmoladun et al 2025
Fumonisin (FB1, FB2)	Maize and maize by products, high in some corn lots	Hepato and nephrotoxicity, pulmonary effects in some species, impaired performance and immunity	Bryden 2012; Murugesan et al 2015; Pinotti et al 2016; Yang et al 2020; Recharla et al 2022; Akinmoladun et al 2025
Aflatoxins	Poorly stored grains, peanuts, oilseeds	Hepatotoxic, carcinogenic, strong immunosuppressant; reduced growth and egg production	Bryden 2012; Murugesan et al 2015; Malekinejad & Fink-Gremmels 2020; Yang et al 2020; Dey et al 2022; Gómez-Osorio et al 2024; Olariu et al 2025; Akinmoladun et al 2025

### **Mechanisms Underlying Mycotoxicosis and Host-Pathogen Interactions.**

Trichothecenes such as DON inhibit protein synthesis and activate ribotoxic and oxidative stress pathways in intestinal and immune cells, causing apoptosis or dysregulated cytokine production (Pierron et al 2016; Yang et al 2020; Xu et al 2022; Recharla et al 2022). This leads to disruption of tight junctions, increased gut permeability, and altered barrier function, facilitating bacterial translocation and colonization, as demonstrated by enhanced *Salmonella* shedding in DON-exposed pigeons (Antonissen et al 2016; Pierron et al 2016; Xu et al 2022; Recharla et al 2022). Aflatoxins, fumonisins, ochratoxin A and zearalenone similarly induce oxidative stress, mitochondrial dysfunction, and immune dysregulation, though with toxin specific organ tropism (e.g., liver for aflatoxin, kidney for OTA, reproductive organs for ZEN) (Murugesan et al 2015; Pierron et al 2016; Yang et al 2020; Holanda & Kim 2021; Dey et al 2022; Gómez-Osorio et al 2024; Olariu et al 2025; Akinmoladun et al 2025). Co-occurrence of multiple toxins produces additive or synergistic effects on oxidative stress, apoptosis, immunosuppression, and organ damage, often at concentrations where individual toxins would be considered "safe" (Murugesan et al 2015; Pinotti et al 2016; Magnoli et al 2019; Holanda & Kim 2021; Xu et al 2022; Kolawole et al 2024; Akinmoladun et al 2025). Masked mycotoxins (plant-conjugated forms) and metabolites such as DON 3 $\alpha$  sulfate may escape routine analytical detection but can be converted back to toxic parent compounds or exert their own biological effects in the digestive tract (Antonissen et al 2016; Xu et al 2022; Kolawole et al 2024; Okasha et al 2024).

In poultry, mycotoxins compromise mucosal immunity and gut integrity, increasing

the severity of coccidiosis, salmonellosis and viral infections; similar mechanisms likely operate in pigeons, especially when they are exposed to pathogens during racing, commingling, or stressful conditions (Murugesan et al 2015; Antonissen et al 2016; Pierron et al 2016; Kolawole et al 2024; Gómez-Osorio et al 2024; Okasha et al 2024; Olariu et al 2025). In pigs, mycotoxin-induced immune alterations reduce vaccine efficacy and predispose to reactivation of chronic infections, underlining the broader relevance of these mechanisms for any intensively managed bird or mammal species (Pierron et al 2016; Recharla et al 2022).

**Risk Mitigation and Decontamination Strategies: Relevance to Pigeons.** Given that prevention of mycotoxin formation in the field is only partially achievable, mitigation focuses on feed hygiene, monitoring, physical/chemical/biological detoxification, and in-feed detoxifying agents (Bryden 2012; Murugesan et al 2015; Pinotti et al 2016; Čolović et al 2019; Malekinejad & Fink-Gremmels 2020; Dey et al 2022; Xu et al 2022; Gómez-Osorio et al 2024; Akinmoladun et al 2025). Good agricultural and storage practices—proper drying, low humidity, temperature control, and rapid use of high-moisture grains—reduce fungal growth and initial contamination in raw materials used for pigeon feeds (Bryden 2012; Pinotti et al 2016; Dey et al 2022; Gómez-Osorio et al 2024; Akinmoladun et al 2025). Systematic surveillance using modern analytical methods such as LC MS/MS is essential to detect multi-mycotoxin contamination and masked forms in both ingredients and complete feeds; surveys show widespread low-level contamination in all major feed commodities (Bryden 2012; Murugesan et al 2015; Antonissen et al 2016; Pinotti et al 2016; Magnoli et al 2019; Xu et al 2022; Kolawole et al 2024; Okasha et al 2024; Akinmoladun et al 2025).

Physical and chemical decontamination methods include cleaning and sorting of grains, ammoniation (mainly effective for aflatoxins but can reduce nutritional value), and ozonation; however, their applicability to small-scale pigeon feed production is limited and often toxin-specific (Čolović et al 2019; Malekinejad & Fink-Gremmels 2020). Feed additives are therefore widely used as a practical on-farm mitigation tool. Clay minerals (e.g., modified clinoptilolite), activated charcoal, yeast cell wall components, and complex multicomponent products can adsorb or biotransform certain mycotoxins in the gut, reducing systemic exposure (Murugesan et al 2015; Čolović et al 2019; Malekinejad & Fink-Gremmels 2020; Holanda & Kim 2021; Xu et al 2022; Recharla et al 2022; Hung et al 2024; Raj et al 2025). In weaned pigs naturally challenged with a combination of fumonisins, zearalenone and DON, inclusion of a clinoptilolite-based product (MultiSHIELD) reduced removals from pens, medication needs, and improved economic outcomes, largely by supporting health under mycotoxin stress (Hung et al 2024). Another study in pigs exposed to combined DON and ZEN showed that a multicomponent detoxifying agent (MMDA) improved average daily gain and feed conversion while reducing DON residues in kidneys, confirming reduced absorption and improved performance under co-contamination (Raj et al 2025). Poultry-focused reviews similarly emphasize the utility of binders and probiotics (e.g., specific bacteria or yeasts able to biotransform toxins) as part of integrated control programs (Murugesan et al 2015; Čolović et al 2019; Recharla et al 2022; Gómez-Osorio et al 2024; Okasha et al 2024; Olariu et al 2025).

Regulatory frameworks, especially in the EU, have started to recognize feed additives “for the reduction of mycotoxin contamination”, requiring demonstration of binding capacity, safety of degradation products, and efficacy in at least three *in vivo* studies, along with biomarker validation (Murugesan et al 2015; Čolović et al 2019). Nonetheless, most regulations and risk assessments are still based on single-toxin limits in major livestock species, without specific guidance for racing pigeons or for complex multi-mycotoxin and emerging toxin patterns (Bryden 2012; Murugesan et al 2015; Pinotti et al 2016; Magnoli et al 2019; Xu et al 2022; Kolawole et al 2024; Akinmoladun et al 2025). This regulatory gap reinforces the status of pigeon feed contamination as an underexplored niche, where practitioners must extrapolate cautiously from poultry and pig data.

At the loft level, a rational pigeon-focused mitigation strategy would therefore combine: careful sourcing of cereals and by-products; strict storage control to prevent

mold growth; periodic multi-mycotoxin testing (including DON, ZEN, fumonisins, aflatoxins, OTA, and emerging toxins); and strategic use of broad-spectrum binders/biotransforming agents whose efficacy has been demonstrated under multi-toxin challenges in other species (Bryden 2012; Murugesan et al 2015; Antonissen et al 2016; Čolović et al 2019; Xu et al 2022; Holanda & Kim 2021; Recharla et al 2022; Kolawole et al 2024; Gómez-Osorio et al 2024; Hung et al 2024; Okasha et al 2024; Olariu et al 2025; Akinmoladun et al 2025; Raj et al 2025). Given the evidence that DON exposure in pigeons increases Salmonella shedding without obvious clinical deterioration, particular attention to mycotoxin management is warranted in lofts where Salmonella, coccidia or other enteric pathogens are endemic or vaccination programs are heavily relied upon (Murugesan et al 2015; Antonissen et al 2016; Pierron et al 2016; Gómez-Osorio et al 2024; Okasha et al 2024; Kolawole et al 2024; Olariu et al 2025).

**Conclusions.** Mycotoxicosis in pigeons should be recognized as a relevant nutritional and health risk, despite the current lack of extensive species-specific research. Evidence from feed analyses demonstrates that pigeon diets are frequently exposed to multiple mycotoxins, often at subclinical but biologically meaningful concentrations. Although overt clinical mycotoxicosis may be rare in pigeons, experimental and comparative animal data strongly indicate that chronic exposure can impair gut integrity, immune competence, and overall performance, while increasing susceptibility to infectious diseases.

Deoxynivalenol and other trichothecenes, along with aflatoxins, fumonisins, zearalenone, and ochratoxin A, exert their effects primarily through oxidative stress, disruption of epithelial barriers, and immunomodulation. Importantly, co-occurrence of multiple toxins can result in additive or synergistic toxicity, complicating risk assessment based on single-compound thresholds. Pigeons may therefore experience subclinical but functionally significant health impairment under routine feeding conditions.

Effective mitigation requires an integrated approach combining strict feed hygiene, optimized storage conditions, regular multi-mycotoxin monitoring, and the strategic use of detoxifying feed additives such as adsorbents and biotransforming agents. However, current regulatory frameworks and scientific evidence remain largely extrapolated from poultry and swine, underscoring a critical need for targeted research in pigeons. A One Health-oriented perspective is essential for improving feed safety, animal performance, and disease resilience in pigeon populations.

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**Conflict of Interest.** The authors declare that there is no conflict of interest.

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