



Effects of Mycotoxins on Poultry Health

Eman R. Hassan¹, Nagwa S. Rabie¹ and Mona S. Zaki²

¹Department of Poultry Diseases, National Research Centre, Dokki, Giza, Egypt

²Hydrobiology Departments, National Research Centre, Dokki, Giza, Egypt

dr_mona_zaki@yahoo.com

Abstract: A mycotoxicosis is a disease caused by a natural toxin produced by a fungus. In poultry, this usually results when toxin-producing fungi grow in grain and feed. Hundreds of mycotoxins have been identified, and many are pathogenic. Mycotoxins may have additive or synergistic effects with other natural toxins, infectious agents, and nutritional deficiencies. Many are chemically stable and maintain toxicity over time. The significance of mycotoxin problems in poultry is probably considerable as it results in many series problems including immunosuppression, negative impact on broiler production (weight gain and feed efficiency), pigmentation, egg production, and reproductive performance. Some mycotoxins like aflatoxins (AF), ochratoxin A (OTA), fumonisins (FUM), deoxynivalenol (DON) and T-2 toxin significantly affect the health and productivity of poultry species and need strict measures in order to prevent their production as these toxins are thermostable once they are produced are persistent in poultry meat and vital organs causing serious pathological conditions.

The aim of this review is to discuss in detail the important mycotoxins for poultry and their effects, along with the recent developments in prevention strategies.

[Eman R. Hassan, Nagwa S. Rabie and Mona S. Zaki. **Effects of Mycotoxins on Poultry Health**. *Researcher* 2020;12(3):1-5]. ISSN 1553-9865 (print); ISSN 2163-8950 (online). <http://www.sciencepub.net/researcher>. 1. doi:[10.7537/marsrsj120320.01](https://doi.org/10.7537/marsrsj120320.01).

Keywords: Effects; Mycotoxin; Poultry Health

Introduction

The term “mycotoxin” is derived from “mykes” meaning fungi and “toxicon” meaning poison. Mycotoxins are secondary metabolites of low molecular weight produced by a wide range of fungi, principally molds. There are over 200 species of molds that produce mycotoxins. Aflatoxins (AF), zearalenone (ZEN), ochratoxin A (OTA), fumonisins (FUM), trichothecenes such as deoxynivalenol (DON), and T-2 toxin are some of the mycotoxins that can significantly impact the health and productivity of poultry species. Fungal growth and subsequent mycotoxin formation is dependent on a range of factors including seasons, location of grain cultivation, drought and time of harvest. Long term analysis of grain and feed samples worldwide has indicated that it is possible to have grains with extremely high concentrations of mycotoxins, although the overall mycotoxin contamination is low, (Streit et al., 2013a). These data also revealed that mycotoxin contaminated grains typically contain more than just a single mycotoxin.

Mycotoxicosis refers to all of those diseases caused by the effects of toxins produced by moulds. Disease is often subclinical and may be difficult to diagnose. Problems occur worldwide, but especially

climates with high temperature and humidity and where grain is harvested with high water content (Zain, 2011).

A number of different types are recognised: aflatoxins are produced by *Aspergillus flavus* (Ehrlich, 2014); T2 fusariotoxins by *Fusarium* spp. (mouth lesions and thin eggshells) (Ferrigo et al., 2016); ochratoxins by *Aspergillus ochraceus* (interferes with functions of kidney, proventriculus and gizzard) (Wang et al., 2018); rubratoxin by *Penicillium rubrum* (interferes with thiamine metabolism and causes symptoms of deficiency) (Ismail and Papenbrock, 2015).

Mortality is variable but all are detrimental to bird health and are resistant to heat inactivation. The following species may be affected, in decreasing order of susceptibility: ducks, turkeys, geese, pheasants, chickens. The route of infection is by ingestion of fungal spores, which are readily carried in the air. High grain humidity, and damage due to insects, as well as poor storage conditions are major predisposing causes, moreover it was found that once toxins have been formed it is difficult to avoid their biological effects; they also increase susceptibility to bacterial diseases. Both fungal spores and formed toxins are generally highly resistant. Affected flocks return to

normal mortality by 7 to 15 days after removal of the toxins. Some believe that mycotoxicosis is an important factor in fatty liver syndrome (*Murugesan et al., 2015*).

Review

Mycotoxins represent a risk to the feed supply chain with an impact on economies and international trade. A high percentage of feed samples have been reported to be contaminated with more than one mycotoxin. Different mycotoxins produced from different fungal species that causing severe economic losses in poultry industry including the following mycotoxins:

1. Aflatoxicosis:

The aflatoxins are toxic and carcinogenic metabolites of *Aspergillus flavus*, *Aparasiticus*, and others. Aflatoxicosis in poultry primarily affects the liver but can involve immunologic, digestive, and hematopoietic functions. Aflatoxin can adversely affect weight gain, feed intake, feed conversion efficiency, pigmentation, processing yield, egg production, male and female fertility, and hatchability. Some effects are directly attributable to toxins, whereas others are indirect, such as reduced feed intake. Susceptibility to aflatoxins varies, but in general, ducklings, turkeys, and pheasants are susceptible, while chickens, Japanese quail, and guinea fowl are relatively resistant (*Benkerroum, 2019*).

2. Ochratoxicosis:

Ochratoxins are quite toxic to poultry. These nephrotoxins are produced chiefly by *Penicillium viridicatum* and *Aspergillus ochraceus* in grains and feed. Ochratoxicosis causes primarily renal disease but also affects the liver, immune system, and bone marrow. Severe intoxication causes reduced spontaneous activity, huddling, hypothermia, diarrhea, rapid weight loss, and death. Moderate intoxication impairs weight gain, feed conversion, pigmentation, carcass yield, egg production, fertility, and hatchability (*Heussner and Bingle, 2015*).

3. Citrinin Mycotoxicosis:

Citrinin is produced by *Penicillium* and *Aspergillus* and is a natural contaminant of corn, rice, and other cereal grains. Citrinin causes a diuresis that results in watery fecal droppings and reductions in weight gain. At necropsy, lesions are generally mild and involve the kidney (*Ostry et al., 2013*).

4. Fumonisin (FUM):

The FUM are a group of mycotoxins that were first isolated from cultures of *Fusarium verticillioides*

(*moniliforme*) and chemically characterized by *Gelderblom et al. (1988)*. Six different FUM have been identified (A₁, A₂, B₁, B₂, B₃, B₄) and their structures elucidated (*Plattner et al., 1992*). However, fumonisin B₁ (FB₁) has been reported to be the predominant form produced by *Fusarium verticillioides* (*Norred, 1993*). Several other *Fusarium* species and a species of *Alternaria* have also been found to produce FB₁ (*Chen et al., 1992*).

5. Trichothecenes:

Trichothecenemycotoxins are a group of fungal metabolites with the same basic backbone structure and include T-2 toxin, HT-2 toxin, diacetoxyscirpenol (DAS), monoacetoxyscirpenol (MAS), neosolaniol, 8-acetoxynivalenol, 4-deacetylneosalaniol, nivalenol, 4-acetoxynivalenol (Fusarenone-X), DON (vomitoxin), and 3 acetyldeoxynivalenol (*Leeson et al., 1995*). Trichothecenes are the most potent small molecule inhibitors of protein synthesis known and the main toxic effect at the cellular level appears to be a primary inhibition of protein synthesis followed by a secondary disruption of DNA and RNA synthesis (*Leeson et al., 1995*). Toxic effects of trichothecenes include oral lesions, growth retardation, abnormal feathering, decreased egg production and egg shell quality, regression of the bursa of Fabricius, peroxidative changes in liver, abnormal blood coagulation, leucopenia and proteinemia, and immunosuppression (*Danicke, 2002*). Concentrations of T-2 that cause oral lesions are lower (0.4 mg/kg) than concentrations reported to decrease chick performance (3–4 mg/kg; *Leeson et al., 1995*).

Diagnosis:

Mycotoxicosis should be suspected when the history, signs, and lesions are suggestive of feed intoxication, and especially when mouldy ingredients or feed are evident, Toxin exposure associated with consumption of a new batch of feed may result in subclinical or transient disease. Chronic or intermittent exposure can occur in regions where grain and feed ingredients are of poor quality or when feed storage is substandard or prolonged. Impaired production can be a clue to a mycotoxin problem, as can improvement because of correction of feed management deficiencies. Definitive diagnosis involves detection and quantitation of the specific toxin (s). This can be difficult because of the rapid and high-volume use of feed and ingredients in poultry operations. Diagnostic laboratories differ in their respective capabilities to test for mycotoxins and should be contacted before sending samples. Feed and also birds that are sick or recently dead should be submitted for testing. A necropsy and related diagnostic tests should accompany feed analysis if mycotoxicosis is

suspected. Concurrent diseases can adversely affect production and should be considered. Sometimes, a mycotoxicosis is suspected but not confirmed by feed analysis. In these situations, a complete laboratory evaluation can exclude other significant diseases (*Murugesan et al., 2015*).

Mycotoxicosis and Immune System

Aflatoxins are able to bind with both DNA and RNA and inhibit macromolecular synthesis by interfering with transcription and other aspects of protein synthesis. Inhibition of protein synthesis is also a “trademark” of trichothecenes including DON and T-2 toxin through the binding to eukaryotic ribosomes, and as well as OTA by blocking phenylalanine tRNA synthetase. Other most prevalent mycotoxins have structural similarity to biological compounds, such as FUM with the sphingoid bases SA and SO (disrupting the synthesis of sphingolipids-containing cell membrane) and ZEN with estradiol (the most important female sex hormone). Although considerable work has been done to correlate mechanisms of action and immunotoxicity, this aspect is not fully understood yet and deserves further research. However, it has been clearly demonstrated that rapidly dividing and activated cells with a high protein turnover (such as immune, intestinal, and hepatic cells) are predominantly affected by mycotoxins. Some recent work exemplifies this latter point where low doses of mycotoxins were able to impair the proliferation of specific lymphocytes primed and activated by an antigen (e.g., following vaccination), whereas no effect was observed on the total non-specific (i.e., that does not recognize the antigen) population of lymphocytes (*Grenier et al., 2015*). Mycotoxins do not possess immunogenic properties, meaning they are not able to induce an immune response unlike pathogens, but they do interfere with signalling pathways (MAPKs) that are implicated in cell growth, apoptosis or immune responses. As a consequence, the processes leading to the establishment of an efficient immune response are impaired and render the animal more susceptible to infection. (*Bouhet and Oswald, 2005*)

Subclinical Doses of Mycotoxins

Poultry species are considered to be less sensitive to mycotoxins, particularly toxins from *Fusarium*, compared to other species, such as the pig. Many experiments in poultry have reported toxic effects of mycotoxins but at doses not expected in the field. However, recent research give evidence that at levels lower than those that would cause overt clinical mycotoxicoses, mycotoxins modulate immune functions and may decrease resistance to infectious disease. In line with that, recent epidemiological data

indicate high correlation between outbreaks of Newcastle disease and AF contamination of broiler rations (*Yunus et al., 2011*). Feeding broiler chickens 0.3 mg AF/kg of feed significantly reduced antibody titres against Newcastle disease and infectious bursal disease (*Girish and Smith, 2008*). Antibodies are produced by B-lymphocytes, which are programmed in the bursa of Fabricius. The reduced antibody concentration observed in poultry fed AF-contaminated diet is most likely related to lymphoid depletion and inhibition of development and functional maturation of the bursa of Fabricius, at doses as low as 0.1 mg AF/kg of feed. Ducks and broilers fed with concentrations of DON ranging from 3 to 12 mg/kg diet also had decreased antibody titers to common vaccines (Newcastle disease, infectious bronchitis) and a reduction in the mass of the bursa of Fabricius (*Awad et al., 2013*). For both DON and AF, the effects seen in the bursa of Fabricius, and the subsequent impact on antibody, might be a direct consequence of the inhibition of protein biosynthesis.

There is also growing evidence that, depending upon the level and length of exposure to the toxins, a biphasic response is expected. For instance, AF follows a pattern of hormesis, characterized by low-dose stimulation and high-dose inhibition with regard to bird performance (*Diaz et al., 2008*). Similarly, an initial increase followed by a decrease in humoral response (antibody response) with low doses of AF has been documented in poultry. The underlying mechanisms for this temporary increase are not known. In other animal models, DON at low doses promoted the expression of several cytokines and chemokines, whereas high doses exhibited immunosuppressive effects (*Grenier and Applegate, 2013*). There is therefore a need to pay closer attention to the effect of doses lower than those that would cause overt clinical symptoms.

Prevention:

Prevention of mycotoxicosis should focus on using feed and ingredients free of mycotoxins and on management practices that prevent mold growth and mycotoxin formation during feed transport and storage. Regular inspection of feed storage and feeding systems can identify flow problems, which allow residual feed and enhance fungal activity and mycotoxin formation. Mycotoxins can form in decayed, crusted feed in feeders, feed mills, and storage bins; cleaning and correcting the problem can have immediate benefits. Temperature extremes cause moisture condensation and migration in bins and promote mycotoxin formation. Ventilation of poultry houses to avoid high relative humidity also decreases the moisture available for fungal growth and toxin formation in the feed. *Binder, et al. (2007):*

Worldwide occurrence of mycotoxins in commodities, feeds and feed ingredients. *Anim. Feed Sci. Technol.*;137:265–282.

Antifungal agents added to feeds to prevent fungal growth have no effect on toxin already formed but may be cost-effective in conjunction with other feed management practices. Organic acids (propionic acid, 500–1,500 ppm [0.5–1.5 g/kg]) are effective inhibitors, but the effectiveness may be reduced by the particle size of feed ingredients and the buffering effect of certain ingredients. Sorbent compounds such as hydrated sodium calcium aluminosilicate (HSCAS) effectively bind and prevent absorption of aflatoxin. Esterified glucomannan, derived from the cell wall of the yeast *Saccharomyces cerevisiae*, is protective against aflatoxin B₁ and ochratoxins. It reduces toxicity through the binding and reduction in bioavailability of fumonisins, zearalenone, and T-2 toxin. Various other fermentation products, algae and plant extracts, and microbial feed additives have demonstrated ability to bind or degrade mycotoxins and may be applicable and appropriate for the situation (*Liew, 2018*).

Treatment

The most effective treatment is removal of the source of toxins. Addition of antifungal feed preservatives is also helpful. Increasing protein level in the feed until mortality reduces may also be beneficial. Administration of soluble vitamins and selenium (0.2 ppm), along with finely divided copper sulphate in the feed 1kg/ton for 7 days (where approved) has been used (*Berthiller, et.al. (2013): Masked mycotoxins: A review. Mol. Nutr. Food Res.; 57:165–186.*

References

1. Streit E., Naehrer K., Rodrigues I., Schatzmayr G. (2013a): Mycotoxin occurrence in feed and feed raw materials worldwide: Long-term analysis with special focus on Europe and Asia. *J. Sci. Food Agri.*;93:2892–2899.
2. Zain, Mohamed E. (2011): Impact of mycotoxins on humans and animals. *Journal of Saudi Chemical Society*. Volume 15, Issue 2, Pages 129-144.
3. Streit E., Schwab C., Sulyok M., Naehrer K., Krska R., Schatzmayr G. (2013 b) Multi-mycotoxin screening reveals the occurrence of 139 different secondary metabolites in feed and feed ingredients. *Toxins*. 2013b;5:504–523.
4. Awad W. A., Ghareeb K., Bohm J. (2009): Animal feed additive and the effect of the fusarium toxin deoxynivalenol on the electrophysiological measurement of transepithelial ion transport of young chickens with using chamber technique. *Intl. J. Poult. Sci.* 2009;8:25–27.
5. Awad W. A., Hess M., Twaruzek M., Grajewski J., Kosicki R., Bohm J., Zentek J. (2011): The impact of the Fusarium Mycotoxindeoxynivalenol on the health and performance of broiler chicks. *Intl. J. Mol. Sci.* 2011;12:7996–8012.
6. Awad W., Ghareeb K., Böhm J., Zentek J. (2013): The toxicological impacts of the Fusariummycotoxin, deoxynivalenol, in poultry flocks with special reference to immunotoxicity. *Toxins.*;5:912–925.
7. Ehrlich KC. (2014): Non-aflatoxigenic *Aspergillusflavus* to prevent aflatoxin contamination in crops: advantages and limitations. *Front Microbiol.*10;5:50. doi: 10.3389/fmicb.2014.00050. PMID: 24575088; PMID: PMC3918586.
8. Ferrigo D, Raiola A, Causin R. (2016): Fusarium Toxins in Cereals: Occurrence, Legislation, Factors Promoting the Appearance and Their Management. *Molecules*. 13;21(5):627. doi: 10.3390/molecules21050627. PMID: 27187340; PMID: PMC6274039.
9. Wang Y, Wang L, Wu F, Liu F, Wang Q, Zhang X, Selvaraj JN, Zhao Y, Xing F, Yin WB, Liu Y. (2018): A Consensus Ochratoxin A Biosynthetic Pathway: Insights from the Genome Sequence of *Aspergillusochraceus* and a Comparative Genomic Analysis. *Appl Environ Microbiol.* 17;84(19): e01009-18. doi: 10.1128/AEM.01009-18. PMID: 30054361; PMID: PMC6146979.
10. Ismaiel Ahmed A. and Papenbrock Jutta (2015): Mycotoxins: Producing Fungi and Mechanisms of Phytotoxicity. *Agriculture*, 492-537; doi:10.3390/agriculture 5030492.
11. Murugesan GR, Ledoux DR, Naehrer K, Berthiller F, Applegate TJ, Grenier B, Phillips TD, Schatzmayr G. (2015): Prevalence and effects of mycotoxins on poultry health and performance, and recent development in mycotoxin counteracting strategies. *Poult Sci.* 2015 Jun;94(6):1298-315. doi: 10.3382/ps/pev075. 25840963; PMID: PMC4988553.
12. Benkerroum N. (2019): Retrospective and Prospective Look at Aflatoxin Research and Development from a Practical Standpoint. *Int J Environ Res Public Health.*27;16(19):3633. doi: 10.3390/ijerph16193633. PMID: 31569703; PMID: PMC6801849.
13. Heussner AH and Bingle LE. (2015): Comparative Ochratoxin Toxicity: A Review of the Available Data. *Toxins (Basel)*. 22;

- 7(10):4253-82. doi: 10.3390/toxins7104253. PMID: 26506387; PMCID: PMC4626733.
14. Ostry V, Malir F, Ruprich J. (2013): Producers and important dietary sources of ochratoxin A and citrinin. *Toxins (Basel)*. 17; 5 (9):1574-86. Doi: 10.3390/toxins5091574. PMID: 24048364; PMCID: PMC3798874.
 15. Gelderblom W. C. A., Jaskiewicz K., Marasas W. F. O., Thiel P. G., Horak R. M., Vleggaar R., Kriek N. P. J. *Fumonisin (1988): Novel mycotoxins with cancer-promoting activity produced by Fusariummoniliforme*. *Appl. Environ. Microbiol.*; 54:1806–1811.
 16. Plattner R. D., Weisleder D., Shackelford D. D., Peterson R., Powell R. G. (1992): A new fumonisin from solid cultures of *Fusariummoniliforme*. *Mycopathologia*.; 117:23–28.
 17. Norred W. P. (1993): Fumonisin – mycotoxin produced by *Fusariummoniliforme*. *J. Toxicol. Environ. Health*.;38:309–328.
 18. Chen J., Mirocha C. J., Xie W., Hogge L., Olson D. (1992): Production of the mycotoxin fumonisin B₁ by *Alternaria alternata* f. sp. *Lycopersici*. *Appl. Environ. Microbiol.*; 58:3928–3931.
 19. Leeson S., Diaz G. J., Summers J. D. (1995): *Poultry Metabolic Disorders and Mycotoxins*. Guelph, Ontario, Canada: University Books.
 20. Danicke S. (2002): Prevention and control of mycotoxins in the poultry production chain: A European view. *World. Poult. Sci. J.*; 58:451–474.
 21. Liew WP, (2018): Mohd-Redzwan S. Mycotoxin: Its Impact on Gut Health and Microbiota. *Front Cell Infect Microbiol*. 26; 8:60. doi: 10.3389/fcimb.2018.00060. PMID: 29535978; PMCID: PMC5834427.
 22. Yunus, M. M., Salehi, H., & Chenzi, C. (2011). Integrating social networking tools into ESL writing classroom: Strengths and weaknesses. *English Language Teaching*, 5(8), 42-48. <http://dx.doi.org/10.5539/elt.v5n8p42>
 23. Girish, C. K., T. K. Smith, H. J. Boermans, and N. A. Karrow. 2008. Effects of feeding blends of grains naturally contaminated with *Fusarium* mycotoxins on performance, hematology, metabolism and immunocompetence of turkeys. *Poult. Sci.* 87:421–432.
 24. Diaz, D. E., and T. K. Smith. 2008. Mycotoxin sequestering agents: Practical tools for the neutralization of mycotoxins. Pages 323–339 in *The Mycotoxin Blue Book*. D. Diaz, ed. Nottingham Univ. Press, Nottingham, UK.
 25. Girish CK, Smith T. Impact of feed-borne mycotoxins on avian cell-mediated and humoral immune responses. *World Mycotoxin J* 2008;1:105e21.
 26. Grenier B, Applegate TJ. Modulation of intestinal functions upon mycotoxin ingestion: meta-analysis of published experiments in animals. *Toxins* 2013;5:396e430.
 27. Berthiller F., Crews C., Dall'Asta C., Saeger S. D., Haesaert G., Karlovsky P., Oswald I. P., Seefelder W., Speijers G., Stroka J. (2013): Masked mycotoxins: A review. *Mol. Nutr. Food Res.*; 57:165–186.
 28. Binder E. M., Tan L. M., Chin L. J., Handl J., Richard J. (2007): Worldwide occurrence of mycotoxins in commodities, feeds and feed ingredients. *Anim. Feed Sci. Technol.*;137:265–282.
 29. Bouhet S & Oswald IP. 2005. The effects of mycotoxins, fungal food contaminants, on the intestinal epithelial cell-derived innate immune response. *Veterinary Immunology and Immunopathology* 108: 199-209.