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Published by
Science Digital PUBLICATION

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Introduction

Mycotoxins are secondary metabolites produced by various toxigenic fungi mainly belonging to three genera Aspergillus, Fusarium and Penicillium. Ubiquitous occurrence, heat stability and lipophilic nature pose serious threats in terms of toxic syndromes in poultry. The toxicological spectrum of various mycotoxins is very wide encompassing different kind of toxicities viz. acute and chronic toxicities, carcinogenicity, genotoxicity, immunotoxicity, mutagenicity and teratogenicity in animals and poultry (Sharma et al., 2012). Chemically these are of low molecular weight, non-antigenic and majority of them are heat stable.

The FAO estimated that about 25% of human foods and animal feeds are contaminated with mycotoxins. It adversely affects the health and productivity of animals and poultry. In India, the economy of the poultry industry is heavily affected due to wide mycotoxin exposure or contamination. The economic losses are primarily due to the decreased growth rate, feed conversion efficacy, carcass yield, carcass quality and increased susceptibility to other diseases caused due to their immunosuppressive effects among the affected birds (Partial et
Most poultry is sensitive to mycotoxins. This partly depends on the type, age and production categories of poultry, their living conditions and nutritive status and partly on the type, quantity and duration of mycotoxin ingestion.

Out of more than 350 mycotoxins identified in nature, the most concern mycotoxins are Aflatoxins, Ochratoxin, T₂ toxin, Vomitoxin, Zearalenone, Fumonisin, Citrinin, Oosporin, and Cyclopiazonic acid. The synergism occurs naturally between different mycotoxins.

Prevention, control and managemental strategies

Efficient decontamination procedures of poultry feed, use of antifungal agents as well as toxin binders can reduce the hazards of mycotoxins in poultry. Further, various microorganisms are also being employed in their effective control. Dietary strategies include the provision of protein and lipid supplementation, proper storage conditions of feedstuffs and their regular monitoring. 5% fat in the diet can also better the feed conversion efficiency and improve

<table>
<thead>
<tr>
<th>Fungus</th>
<th>Toxin Metabolite</th>
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<tbody>
<tr>
<td>Aspergillus parasiticus</td>
<td>Aflatoxins B₁, B₂, G₁, G₂</td>
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<tr>
<td>Aspergillus flavus</td>
<td>Aflatoxins B₁, B₂</td>
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<tr>
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<td>Deoxynivalenol (Zearalenone)</td>
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<td>Penicillium verrucosum</td>
<td>Ochratoxin A</td>
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<tr>
<td>Aspergillus ochraceus</td>
<td>Ochratoxin A</td>
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Ref: www.biomin.net

![Diagram of mycotoxin effects and interactions](Ref: www.biomin.net)
weight gain in birds. Vitamins such as A, C and E and selenium supplementation are commonly found to be effective in reducing causalities due to mycotoxin contaminated feeds. Feeding of extra vitamins A and K could also decrease the detrimental effects of aflatoxins.

A holistic approach is required to combat the adverse effects of mycotoxins to enhance the overall poultry production. The most effective means of reducing toxin contamination is the prevention of mould growth in feed commodities, by improving the storage methods, harvesting practices and handling of crops. Effective post-harvest management of stored commodities requires clear monitoring criteria. Effective implementation in relation to antibiotic and biotic factors, hygiene and monitoring to ensure that mycotoxin contamination is minimized and that stored grain can proceed through the food chain for processing.

**Managemental Approaches**

1. **Mycotoxin Screening:** Routine analysis of feed ingredients and feedstuffs for mycotoxin contamination before the formulation of poultry ration is important.

2. **Moisture/Temperature:** Monitoring and control of moisture are critical in the prevention of fungal growth and mycotoxin production. The moisture level of grains should be kept at/below 13% (Sharma et al., 2012).

3. **Cleaning:** Periodic cleaning of all feed handling equipment’s with 5% to 10% bleach solution will help in controlling mould growth.

4. **Feed holding time:** It is important to keep the time from the manufacture of feed to when it is consumed by the birds as short as possible.

5. **Withdrawal and change of mycotoxin-contaminated feed/feed ingredients** at the farm could provide partial protection to poultry from the toxicity as well as mycotoxin residues.

**Physical methods**

1. **Mechanical separation:** Toxin levels decrease as clean product is physically separated from contaminated grains.

2. **Density segregation:** Density segregation of contaminated grain and oilseed by floatation can notably decrease various mycotoxin concentrations in contaminated grains.

3. **Irradiation:** Gamma or electronic irradiation is highly effective for destroying the fungal spores. Fluorescent or ultraviolet rays decompose aflatoxins and ochratoxins. Applying UV light for 20 minutes at 25°C in the presence of peroxide (0.05%) decreases aflatoxin concentration.
exposure of contaminated grains to sunlight (UV) substantially reduces mycotoxin levels (Katole et al., 2013).

4. **Antimycotic agents:** Antimycotic agents like sorbic acid and sorbate; propionic acid and propionate, benzoic acid, benzoates and parabens; and acetic acid and its derivates are the chemicals that prevent mould growth and interfere with mycotoxin production. Hydroxyquinoline and gentian violet are good mould inhibitors.

**Chemical detoxification**

1. **Structural Degradation:** Numerous chemicals including acids, bases, aldehydes, bisulfites, oxidizing agents and various gases successfully destroy mycotoxins.

2. **Ammoniation:** Treatment with aqueous and gaseous ammonia or ammonium hydroxide, with or without heat and pressure to destroy the mycotoxin in contaminated food and feed is currently the best and effective method. Ammoniation not only detoxifies several mycotoxins (85-100% reduction) but also inhibits mould growth.

3. **Ozonization:** Ozone (O₃) gas, a powerful oxidant, decomposes aflatoxins in corn and cottonseed meals and also degrades deoxynivalenol.

4. **Sodium hydroxide:** Warming of grain to 105 °C in the presence of 0.5% sodium hydroxide detoxifies various mycotoxins in the feed.

**Biological inactivation/amelioration**

**Mycotoxin-binding agents**

Based on deactivation of mycotoxins directly in the gastrointestinal tract (*in vivo*), various nutritionally inert sorbents have currently been used to counteract the mycotoxin toxicity in poultry. These are hydrated sodium calcium alumina silicate (HSCAS), Bentonites, Activated charcoal, Cholestyramine, Polyvinylpolypyrrolidone (a synthetic resin, can build up to 50g/kg of AFB₁ in feed), Bovine serum albumin (BSA), which competes with mycotoxins in the intestinal tract and helps to excrete these. Microbiological binding agents like Mannan oligosaccharide (MOS), extracted from the cell wall, esterified with glucan, can bind Aflatoxin B₁, Zearalenone, T₂ toxin and Ochratoxin. *Saccharomyces cerevisiae* has shown broad-spectrum efficacy against most of the mycotoxins (Asrani et al., 2013).

Certain strains of lactic acid bacteria, *propionibacteria* and *bifidobacteria* have cell wall structures that can bind mycotoxins and limit their bioavailability in the body. Biological detoxification degrades aflatoxins by fungus or microbes and reduces mycotoxin contamination by competitive inhibition with the toxigenic fungi. Non-toxigenic *Aspergillus* spp. has...
been shown to significantly reduce the growth of toxigenic Aspergillus species. Flavobacterium aurantiacum possesses activity to degrade aflatoxins. Recently, Saccharomyces cerevisiae and lactic acid bacteria have been found to be effective biological detoxifying agents. Modified glucomannans, a derivative of the yeast cell wall, are beneficial in binding to higher levels of mycotoxins. Nocardia corynebacteroides has also been found safe for chicks and may be used to partly detoxify chicken feed contaminated with aflatoxin.

**Nutritional Management**

Feeding of high protein, methionine or cysteine through diet decreases the growth depression effect of aflatoxins. Synthetic antioxidants (butylated hydroxytoluene, ethoxyquin, beta-naphthoflavone) stimulate detoxification enzyme system in the liver. Selenium, a component of glutathione peroxidase promotes the clearance of toxin by enhancing the formation of a water-soluble conjugated form of aflatoxin. Supplementary vitamin C is beneficial in counteracting the toxic effects of T2 toxin in the hen. High fat or fiber containing diets also reduces the toxicity of aflatoxins.

**Antioxidant substances**

The protective properties of antioxidants like selenium, chlorophyll and its derivatives and vitamin A, C, E are probably due to their ability to act on superoxide anion thereby protecting cell membranes from the mycotoxin induced damage. Efficacy of turmeric (Curcuma longa) powder (TMP), possessing antioxidant properties, has been found to be helpful in reduction in the severity of AFB1 toxicity (Sharma et al., 2012).

**Ascorbic acid (Vitamin C):** Ascorbic acid has been shown to react directly with superoxide, hydroxyl radical and singlet oxygen in addition to direct quenching of reactive free radical.

**Vitamin E/Selenium:** It partially counteracts the formation of lipid peroxides due to single and combined exposure to OTA and T2 toxin.

**Vitamin A:** Carotenoids mainly carotene and xanthophylls present in carrots; palm oil and maize possess the antioxidant property and also the anti-mutagenic and anticarcinogenic properties and reduce toxicities of OTA.

**Food components and additives**

Numerous food components, ingredients, or additives with or without antioxidant properties have been found to have ameliorative properties against mycotoxicosis.

**L-Phenylalanine:** OTA has been reported to inhibit protein synthesis by competition with phenylalanine. Supplementation of 0.8% to 2.4% phenylalanine in broiler diets containing 4ppm decreased the mortality rate from 42.5% in non supplemented chicken to around 14% (Zain et al., 2011).

**L-Methionine:** It has a protective effect against many oxidant
drugs, and plays an important role in preserving the structure of cell membrane and in modulating the antimicrobial of polymorphonuclear leukocytes and behaving as chemotherapeutic agents. It has a good role in hepatitis treatment.

**Aspartame:** A structural analog of both OTA and phenylalanine has been shown to have a protective effect against OTA induced cytotoxicity in animals.

**Crude protein:** Raising the protein levels of diet from 14-18% to 22-26% counteracts the OTA effects.

**Dietary lipids:** 2, 6, or 16% cottonseed oil into semi-purified diets containing 10 ppm aflatoxin not only improves the body weights, but the mortality is also significantly reduced.

A significant protective effect of the feed additives or material like water extract of artichoke (WEA), sesame seed (SS), Roxazyme-G (RG) and 1-beta phenylalanine (PHE) against the suppressive effect of ochratoxin A (OTA) on egg production of laying hens has been reported. Nitrosative tissue degeneration caused by aflatoxin could be greatly reduced by melatonin supplementation in chicks.

**Some of the salient points are**

- Always purchase feed and feed supplements from safe and certified manufactures and agencies.
- Continual vigilance with top priority to safeguard and ensure clean production of poultry feed, keeping in mind the importance of analysis of feeds at regular intervals.
- Prevent fungal growth on crops in the field, at harvest of the crop, during storage of feedstuffs and processing of feed.
- Proper ventilation of feed stores is needed to avoid high relative humidity which provides a suitable environment for fungal growth.
- Pelleting of feed helps in the destruction of most of the fungal spores.
- Prevention can be achieved by using effective preservation methods e.g. 1.5% acetic acid–propionic acid mixture (60:40) in the feed and 2% of gentian violet or 1-2% ammonia treatment of the feed are among the standard methods (Asrani et al., 2013).
- Antifungal agents have to be added to feeds to prevent fungal growth to inhibit toxin production.
- Exposure of contaminated grains to sunlight (UV) can substantially reduce the level of mycotoxin in feeds. Chemical detoxification can be achieved by treating with sodium hydroxide and sodium bisulfite. Ethylene also inhibits aflatoxin synthesis and can be used to reduce aflatoxin contamination.
- Application of appropriate
mycotoxin binder in order to achieve good productivity and economy, viz. HSCAS, bentonites, activated charcoal, Cholestyramine, Polyvinylpolypyrrolidone, aluminas, zeolites, silica, and phyllosilicates (Zain et al., 2011). Microbial binders are used for the biological detoxification like S. cerevisiae, MOS, non-toxigenic Aspergillus spp and F. aurantiacum.

- Spice oils such as clove and cinnamon oil have been reported to inhibit the growth of Aspergillus.

- Nutritional management and antioxidant compounds, medicinal herbs and plant extracts reduce the adverse effects of mycotoxins.

**Conclusion**

The possibility and utility of treatment in birds are minimal once mycotoxicosis is established in a flock. However, an immediate change of the feed and providing fresh feeds to the birds along with the above-mentioned approaches help reduce the negative health impact of mycotoxins in birds. Broad-spectrum antibiotics should be supplemented to avoid secondary complications together with following good sanitation, hygiene and biosecurity practices, in and around the poultry habitat, to limit the entry of other pathogens of poultry. Supplementation of liver tonics may also be helpful to control the damage to vital organs and help in reducing the mortality in flocks. Appropriate prevention, treatment and vaccination regimens against common poultry pathogens will help to preventing or removing additive or synergistic interactions.

**REFERENCES**


