# Aflatoxins in feeds: Issues and control measures

**Narayana Rathode[1#], Sakshi[2], Trishna Das[3], Abhishek Sharma[4], Lavudya Naveen[5]**

[1]Assistant Professor, Department of Animal Nutrition, Apollo College of Veterinary Medicine, Jaipur -302031, Rajasthan, India
[2] PhD Scholar, Division of Medicine, ICAR- Indian Veterinary Research Institute, Izatnagar-243122 Uttar Pradesh, India
[3]Assistant Professor, Department of Animal Nutrition, Centurion University, Paralakhemundi- 761200, Odisha
[4] MVSc Scholar, Department of Animal Nutrition, PGIVER, Jaipur -302031, Rajasthan, India
[5] Assistant Professor, Department of Veterinary Physiology & Biochemistry, Apollo College of Veterinary Medicine, Jaipur -302031, Rajasthan, India
[#] Corresponding author. email : narayanarathode024@gmail.com
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***Abstract***

Aflatoxins are low molecular lipophilic compounds produced by mycotoxigenic fungi such as *Aspergillus flavus, A. parasiticus* and few other genera. Chemically they are difuro coumarin derivatives and are ubiquitous in nature. The major types include aflatoxin B1, B2, G1, and G2, while M1 and M2 are metabolites of B1 and B2, respectively, are found only in animal products. Commonly affected feeds include maize, groundnut cake, and cottonseed cake. Fungal growth and toxin production are favoured by hot, humid climate and biotic or abiotic stressors. These toxins are resistant to heat but degraded by UV light. They are highly toxic, causing hepatotoxicity, immunotoxicity, embryotoxicity, and teratogenicity, and can accumulate in meat, eggs, and milk. Regulatory limits are established globally, including BIS in India. Control involves pre and post-harvest management, detoxification technologies, and nutritional interventions such as protein-rich diets, vitamins, minerals, and amino acid supplementation to reduce toxicity in affected animals. Preventive practices remain essential to safeguard animal health, productivity, and food safety.

## Introduction

Recently, Indonesia suspended Indian groundnut imports for higher aflatoxin (AF) levels, effective from September 2025 (The Hindu Bussinessline, Aug 29, 2025). This explains the magnitude of fungal toxin contamination of Indian feeds and foods. Mycotoxigenic fungi most prevalent feed safety issue in livestock feed, with aflatoxins being among the most prevalent and harmful. AFs are secondary metabolites primarily produced by *Aspergillus flavus*, *A. parasiticus*, and related species, and are considered unavoidable contaminants due to their persistence in agricultural systems. They cannot be detected by sight or smell in contaminated food or feed and are resistant to common processing methods such as boiling, cooking, or pelleting. Major feed ingredients including maize, rice, barley, wheat, sorghum, and oilseeds particularly groundnuts are highly susceptible to contamination, with maize and groundnut being most affected.

The impact of AFs on animal and human health is well documented. Dietary levels as low as 10-20 ppb result in detectable metabolites such as AF M1 and M2 in milk, posing risks for consumers. In poultry, feeding at 3,000 ppb can lead to 3 ppb residues in meat, with the highest concentrations found in the kidney, liver, and gizzard. Beyond livestock, AF contaminated foods have triggered severe public health crises. In the year 1974, Gujarat and Rajasthan states, hepatitis epidemic caused over 100 deaths due to *A. flavus* contaminated maize. More recently, outbreaks have been reported in Europe, including Romania, Serbia, and Croatia, linked to contaminated milk (Kumar et al., 2017).

Global feed and food contamination is widespread. Surveys show that 30% of feed samples in Asia-Pacific and 52% in Europe-Mediterranean tested positive for at least one mycotoxin, while African studies also report high levels of contamination. FAO estimates nearly 1,000 million tonnes of food lost annually due to mycotoxins, which often occur in combination, leading to synergistic toxic effects. Among them, AF B1 is the most potent, exerting hepatotoxic, immunosuppressive, and carcinogenic effects, while enhancing hepatitis B virus associated liver cancer and inducing oxidative stress and apoptosis. Regulatory residue limits vary widely, with AFM1 in milk set at 50 ng/kg in the European Union (EU) and 500 ng/kg in the US, and AFB1 in feeds ranging from 5 µg/kg (EU) to 20 µg/kg (US). As AFs cannot be eliminated once present, preventive strategies are essential, including improved production practices, use of ammonization or binders, and rapid detection methods like ELISA and HPLC. Strengthening surveillance, laboratory capacity, and low-cost detoxification technologies remains critical to safeguard feed safety, livestock productivity, and public health.

**Modes of absorption and transmission**

AFs enter animals primarily via ingestion, inhalation of spores or mycelial fragments, and transplacental transfer, through milk. Absorption occurs efficiently in the gastrointestinal tract through passive diffusion, while lipophilic non-ionized forms may cross membranes via diffusion in the lipid phase. In the liver, cytochrome $P_{450}$ enzymes metabolize AFB1 to reactive intermediates such as AFB1-8,9-epoxide and less toxic metabolites (AFP1, AFQ1, AFB2a), while aflatoxicol and AF M1 form in milk-producing animals. Reactive epoxides covalently bind DNA or proteins, forming AFB1-albumin adducts, causing mutagenesis, hepatotoxicity, and immunosuppression. AFs impair phagocytosis, chemotaxis, cytokine synthesis, and reduce vaccine efficacy. Poultry susceptibility varies (ducks > turkeys > broilers > layers). Chronic exposure decreases plasma minerals (Ca, P, Mg, K, Zn), reduces rumen motility, disrupts antioxidant defenses, and elevates ROS, NOS, TNF-α, and CXCL2 expression. Dietary interventions such as polyphenols and smectite clays can mitigate hepatocarcinogenesis and clinical toxicity.

**Analytical detection of aflatoxins in feeds**

Accurate detection of AFs in animal feeds is critical for food safety, with methods including TLC, ELISA, HPLC, LC-MS/MS, and electrochemical immunosensors. Among these, HPLC offers superior sensitivity, precision, and reliability. Effective analysis requires proper sample pretreatment, including classical solid-liquid extraction, microwave- or ultrasonic-assisted extraction, and clean-up using solid-phase extraction, immunoaffinity columns, multifunctional or molecularly imprinted polymers, and combined QuEChERS protocols. Recent advances include magnetic adsorbents ($Fe_3O_4@SiO_2@TiO_2$) functionalized to increase binding sites for enhanced toxin recovery. While pasture, hay, straw, and silage may contain low AF levels, the major source for animals is commercial feed. Obtaining representative samples is crucial, as improper sampling or extraction can compromise accuracy. Rapid on-site tests are available for preliminary screening. Accreditation of local laboratories and ring tests are essential to ensure result reliability, with high-risk feeds such as maize, groundnut, oilseeds, and commercial concentrates requiring focused monitoring for both intensive and smallholder farms.

**Handling and detoxification of contaminated feeds**

AF contaminated feeds can be managed through diversion, destruction, sorting, cleaning, and chemical or biological detoxification. Physical sorting reduces contamination by 40-80%. Thermal treatments like extrusion above 160 °C, roasting, and baking, can reduce AFB1 levels by 40-80% depending on matrix and process efficiency. Chemical detoxification methods include ammoniation (>99% reduction), ozonolysis (78–95%), and alkaline treatments, which cleave the lactone ring of AFs. Adsorbents like clays, zeolites, charcoal, glucomannans, and yeast derivatives bind AFs in the gastrointestinal tract, mitigating toxic effects in pigs and poultry. Humic acid, lactic acid bacteria, and certain probiotics can both bind and degrade AFs (Pierides et al., 2014).

**Pre and post-harvest preventive strategies**

Pre-harvest measures include crop rotation, pest control, irrigation, fertilization, early harvesting, and the use of resistant varieties or non-aflatoxigenic *Aspergillus* strains. Post-harvest strategies focus on proper storage such as controlled humidity, temperature, aeration, and use of chemical preservatives like sorbic and propionic acid to prevent fungal growth (Singh et al., 2021). Biological approaches, including fermentation with *A. niger*, non-aflatoxigenic *A. flavus*, and lactic acid bacteria, have shown effective detoxification of AFB1 (Afshar et al., 2020). Emerging green technologies such as cold plasma, high-pressure processing, pulsed electric fields, and nanomaterials ($Fe_3O_4$, chitosan coated nanoparticles) are promising for rapid surface detoxification of grains (Alizadeh et al., 2021).

**Nutritional and palliative methods**

AFs deplete methionine in the methionine glutathione system, impairing growth and feed efficiency. Choline, synthesized in the liver, supports hepatic function, and supplementation may be required under mycotoxin stress. Vitamin $D_3$ metabolism depends on liver conversion. Feeding Vitamin $D_3$ bypasses this step, ensuring efficient utilization. Additional interventions include protein-rich diets, amino acids, vitamins, minerals, polyphenols, and smectite clays, which reduce hepatotoxicity, oxidative damage, and clinical aflatoxicosis. Together, preventive practices and targeted nutritional supplementation are critical to safeguard livestock productivity, health, and food safety.

Dietary interventions can mitigate aflatoxicosis in livestock. Protein-rich diets, amino acid supplementation (methionine, arginine), vitamins A, D, E, K, and B complex, and trace elements (Cu, Zn, Fe, I) improve liver function, antioxidant capacity, and nutrient utilization under aflatoxin exposure (He et al., 2016). Methionine depletion impairs glutathione synthesis, while arginine enhances NO production, supporting antioxidant defenses.

**Economic impact of aflatoxicosis**

AF contamination in animal feeds imposes significant economic burdens on producers, consumers, and governments. Livestock producers face reduced milk and egg yields, slower growth rates, increased feed costs, higher veterinary expenses, and elevated morbidity. Consumers, particularly infants and young children, bear indirect costs through higher prices of animal products and potential health risks. Governments experience trade disruptions, exemplified by the EU's 5 ppb groundnut standard, which has curtailed Africa-EU trade. Globally, approximately 4.5 billion people are chronically exposed to AFs, resulting in morbidity, mortality, and intangible costs such as pain, anxiety, and reduced quality of life. Chronic mycotoxicosis, often difficult to diagnose due to overlapping symptoms and multiple mycotoxin contamination, contributes to substantial but hard to quantify economic losses, underscoring the need for effective prevention, monitoring, and mitigation strategies in feed and food systems.

In conclusion, AFs pose a critical threat to livestock productivity and human health through immunosuppression, hepatotoxicity, and mycotoxin carryover into animal products. Integrated management, including pre and post-harvest interventions, dietary mitigation, advanced detection and biocontrol remains essential to ensure feed safety, reduce economic losses, and minimize chronic exposure risks globally.