An overview of Mycotoxin contamination of animal feeds

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Abstract

Mycotoxins contamination of animal feeds remains a great concern for animal feed safety, public health and economic significance. It may occur in various foods and feeds stuffs from agricultural commodities to finished foods and feeds of animal. Hot, humid weather and late harvesting of grains favored the mold and fungal growth in cereal crops. There are around 400 types of mycotoxins in which aflatoxin, deoxyinalenol (vomitoxin), fumonisin, zearalenone and ochratoxins are important for animal and human foods. However, presence of mold or fungi in the grains does not mean that mycotoxins are present in feeds or foods. The acceptable level of aflatoxins, deoxyinalenol (vomitoxin), fumonisin, zearalenone and ochratoxins are in livestock feeds are 20 ppb, 10 ppm, 5 ppm and 3-10 ppm and 3-20 (µg/kg) respectively. Mycotoxins can be found in contaminated cereal grains, straw and silage. The most detrimental effects of mycotoxins are hepatic, digestive, immunological, reproductive disorders, teratogenicity, nephrotoxicity, edema and carcinogenicity etc. of animal and human being. Adsorbents and activated charcoal in animal feeds bind the toxic substances. There are some regulations but not in all countries aimed to prevent and control mycotoxins in industrial processed foods and animal feeds but not in locally processed ones. A number of strategies in some countries for preventing mycotoxins have been mobilized but the awareness for implementation is very weak. Mass media can play an important role to build awareness to mycotoxin.

(**Key words:** Feeds, grains, mycotoxin, contamination, effects, prevention.)

Introduction

Mycotoxins are toxic secondary metabolites produced by fungi (molds). Only few molds produce mycotoxins, and they are referred to as toxigenic. The primary classes of mycotoxins are aflatoxins of which aflatoxin B1 (AFB1) is the most prevalent, zearalenone (ZEA), trichothecenes, deoxy- nivalenol (DON) and T-2 toxin (T-2), fumonisins, ochratoxins (OTA) (Whitelow *et al.*, 2010). These can cause toxicity in a variety of species. Feeds and forages can become contaminated with mycotoxins in the field, during harvest, drying and transport, as well as during storage (Sarah and Vickers, 2016). Mycotoxin contamination of feeds results in economic loss and transmission of toxins in the food chain. Animal feeds, the raw ingredients used in manufacturing, namely, maize, wheat, sunflower seeds, cottonseeds, bagasse, wheat bran, gluten feed and pet foods are contaminated with mycotoxin- producing fungi and their toxins: aflatoxins, fumonisins, zearalenone and ochratoxins (Phakamile *et al.*, 2007). Disease outbreaks due to the consumption of contaminated foods and feeds stuff are a recurring problem worldwide. The major factor contributing to contamination are microorganisms, especially fungi, which

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produce low-molecular-weight compounds as secondary metabolites, with confirmed toxic properties referred to as mycotoxins (Rajeev *et al*., 2009). Mycotoxin contaminations of foods and feeds remain a great concern to food safety and of public health and economic significance. Health implications of mycotoxins are diverse. Mycotoxicity of foods have tremendous effect on international trade, resulting in huge losses. A number of strategies for preventing mycotoxins have been proposed but the awareness for implementation is very low. The use of media to create awareness is a viable option (Ukwuru *et al.*, 2017). Mycotoxins are toxic to both animals and humans and that are mainly produced by five genera: *Aspergillus, Fusarium, Penicillium, Claviceps* and *Alternaria* (Ruima *et al*., 2018). Fungi proliferate to produce secondary metabolites under favorable environmental conditions, when temperature and moisture are suitable (Bryde, 2009). The amount of toxin produced will depend on physical factors (moisture, relative humidity, temperature and mechanical damage), chemical factors (carbon dioxide, oxygen, composition of substrate, pesticide and fungicides), and biological factors (plant variety, stress, insects, spore load). These toxins (aflatoxin, ochratoxin, fumonisin, deoxynivalenol) produced by fungal species remain stable throughout the processing periods and cooking of feeds and foods. Fungal infection and subsequent production of mycotoxin can occur at the field during crop growth or harvesting, and may continue during storage. The occurrence of this mycotoxin at a considerably high level of concentration in foods can cause toxic effects ranging from acute to chronic manifestations in humans and animals (Richard, 2007). Animals that have been fed with Mycotoxin contaminated feeds release products which can be dietary sources of some mycotoxin (Prelusky, 1994). The economic impact of mycotoxin is diverse; loss of human and animal life, reduced livestock production, disposal of contaminated foods and feeds and investment in research (Hussein *et al.*, 2001). So many efforts have been made towards control and reduction of mycotoxin contamination of foods but the ubiquitous nature of toxigenic fungi enables their wide occurrence. It is also noted that in most rural areas of the world, no effort is made towards the control of toxigenic fungi in food contamination. This paper has reviewed mycotoxin contamination in animal feeds.

Mycotoxins contaminations in animal feeds

Animal feed contaminations with mycotoxin

Mycotoxins usually found in grain during growth and storage, silage and straw preparation. Feeds become contaminated with mycotoxin during preservation and storage. Aflatoxins, fumonisins, ochratoxin A, trichothescenes and zearalenone are considered as the most alarming mycotoxins that affect livestock production. Mycotoxin production is influenced by pre-and post-harvest temperature, agronomic practice, carbon dioxide and moisture and humidity levels. Generally, mycotoxin contamination is most likely to occur in warm, wet conditions. It is thought ruminants are less susceptible to mycotoxins than other species, because the bacteria which make the rumen function can degrade certain mycotoxins into a less toxic form, providing some protection (Rahman *et al.*, 2018). However, some mycotoxins can resist breakdown and prolonged exposure to mixtures of mycotoxins can impair the function of the rumen microbes (Sarah and Mary, 2016).

Source of contaminations with mycotoxin

Mycotoxins are very stable compounds that can survive on the grain long time after the initial mould has disappeared, so the absence of mould does not mean the crop is clean. Fusarium mycotoxin occurrence may be greater when wet weather delay harvesting. Storage fungi can grow on cereals from about 14.5% moisture content (7.5-8% in oilseed) and these can causes losses of germinates capacity, furthermore may produce mycotoxins. Ochratoxin- A may be produced by the storage of mould *Penicillium verrucosum* if grain exceeds 18% moisture content. Moreover, the significant risk occurs during ambient air-drying which may takes weeks to dry. Straw may contain higher concentrations of *Fusarium* mycotoxins. *Aspergillus, Penicillium* and *fusarium* are considered to be the most important moulds and producers of mycotoxins in silage (Sarah and Vickers, 2016).

Risk factor for mycotoxin contaminations in animal feed

According to Sarah and Vickers, 2016, risk factors for mycotoxin contaminations in animal feeds are crop debris, high humidity, early sowing and dry weather. More resistant varieties have a lower risk of *Fusarium* mycotoxin contamination. Aflatoxin B1 is reported to be the more carcinogenic than others. Ducklings are 5 to 15 times more sensitive to aflatoxins than laying hens. Stress, physical state, nutritional level and disease condition also determine the response of animal to mycotoxin.

Molds growth and formation of mycotoxins

The major mycotoxin-producing fungal genera are *Aspergillus, Fusarium* and *Penicillium.* Many of these fungi produce mycotoxins in feedstuffs. Molds usually grow and produce mycotoxin during pre-harvest or during storage, transport, processing or feeding stages. Mold growth and mycotoxin production are related to plant stress caused by weather extremes, insect damage, inadequate storage practices and faulty feeding conditions (Coulumbe, 1993). Molds grow over a temperature range of 10-40°C (50-104°F), a pH range of 4 - 8 and moisture content >13-15%. Most molds are aerobic, and therefore high-moisture concentrations that exclude adequate oxygen can prevent mold growth. Molds usually grow in wet feeds such as silage or wet byproducts, when oxygen is available. *Aspergillus* species normally grow at lower water activities and at higher temperatures than the *Fusarium* species. Therefore, Aspergillus flavus and aflatoxin in corn are favored by the heat and drought stress associated with warmer climates (Klich *et al.*, 1994). Aflatoxin contamination is enhanced by insect damage before and after harvest. The individual *Penicillium* species have variable requirements for temperature and moisture but are more likely to grow under post- harvest conditions, in cool climates, in wet conditions and at a lower pH. The *Fusarium* species are important plant pathogens that can proliferate pre-harvest, but continue to grow post-harvest. *Fusarium* molds are associated economically important diseases, causing ear rot and stalk rot in corn and head blight (scab) in small grains. In wheat, *Fusarium* is associated with excessive moisture at flowering and early grain-fill stages (CAST, 2003).

Acceptable range of mycotoxins in foods and animal feeds

The acceptable level of Mycotoxins in human foods according to European Commissions (2007) is shown in Table 1. (Ukwuru *et al.*, 2017).

Table 1. European Commission (2007) maximum limits for Mycotoxins in foods

SL No.	Type of Toxin	Causal agent	Food item and product	Maximum limit (µg/kg)
1	Aflatoxin	*Aspergillus flavus, A. parasiticus, A. nomius, A. A. bombycis, A. ochraceoroseus, A. pseudotamari*	Peanuts, oilseeds, cereals, processed products	4
			Tree nuts, dried fruits, maize, rice, spices, almonds, pistachios, hazel nuts	10
2	Fumonisins	*Fusarium proliferatum, F. verticillioides*	Processed cereal-based foods	200
			Infant baby foods	400
			Unprocessed maize	800
3	Trichothecenes	*F. sporotrichioides; F. poae*	Processed cereal-based foods	200
			Pasta	750
4	Ochratoxin A	*Penicillium verrucosum, P. auriantiogriseum, P. nordicum, P. palitans, P. commune, P. variabile, Aspergillus ochraceus, A. melleus, A. niger, A. carbonarius, A. sclerotiorum, A. sulphureus*	Processed cereal-based foods	0.5
			Wine, grape juice, grape nectar/must	2
			Roasted/ground coffee beans	5
			Spices	20
5	Patulin	*P. expansum*	Apple juice	10
			Solid apple products	25
			Spirit drink, cider	50
6	Zearalenone	*Fusarium graminearum, F. sporotrichoides, F. culmorum, F. cerealis, F. equiseti, F. incarnatum*	Bread, pastries	50
			Biscuits, cereals, snacks	75

The acceptable level of Mycotoxins in animal feed according to European Commissions (2007) is shown in Table 2. (Sarah and Vickers, 2016).

factors contributing to contamination are microorganisms, especially fungi, which produce low-molecular-weight compounds as secondary metabolites known as mycotoxins

Table 2. The acceptable level of Mycotoxins in animal feed

Serial No.	Type of Toxin	Feedstuff	Maximum content in mg/kg (ppm)
1.	Aflatoxin	All feed materials	0.02
		Complete feedstuffs for beef cattle and sheep	0.02
		Complete feedstuffs for dairy cattle	0.005
		Complete feedstuffs for calves and lambs	0.01
2.	Deoxynivalenol (DON)	Feed materials- Cereal and cereal products	8
		Feed materials- Maize co-products	12
		Complete feedstuffs for sheep, beef and dairy cattle	5
		Complete feedstuffs for calves and lambs	2
3.	Zearalenone (ZEN)	Feed materials- Cereals and cereal products	2
		Feed materials- maize co-products	3
		Complete feed stuffs	0.5
4.	Ochratoxin A	Feed materials- Cereals and cereal products	0.25
5.	Fumonisin B_1 and B_2	Feed materials- Cereals and cereal products	60
		Complete feedstuffs for sheep, dairy and beef cattle	50
		Complete feedstuffs for calves and lambs	20

Ref. : EC, 2007.

Effect of mycotoxin on animal health and production

Outbreaks of disease due to the consumption of contaminated food and feedstuff are a recurring problem worldwide. The major (Rajeev *et al.*, 2010; Ali, 2018). Subacute mycotoxicosis causes symptoms in humans and animals including moderate to severe liver damage, reproductive problems, appetite loss, digestive tract discomfort, diarrhoea, growth faltering, immune suppression, increased morbidity, and premature mortality (Miller *et al.*, 1994). Immune suppression causes increased morbidity and mortality in animals and humans. *Fusarium* toxins called trichothecenes causes severe damage to actively dividing cells in bone marrow, lymph nodes, spleen, thymus, and intestinal mucosa (Cardwell *et al.*, 2000). Hendrickse *et al.* (1991) and Sultana *et al.* (2015) reported that protein–energy malnutrition, kwashiorkor, immune suppression, reduce assimilation of vitamins A and E, carcinogenicity and genotoxicity due to aflatoxicosis (Linsell *et al.*, 1977). Acute aflatoxicosis (severe aflatoxin poisoning) occurs in poultry, swine, and cattle consuming feeds contaminated with aflatoxins. The same can appear in humans, and cases of lethal toxic hepatitis attributed to consumption of aflatoxin-contaminated maize (Marasas *et al.*, 1996). Mycotoxin contamination of feeds results in economic loss and transmission of toxins in the food chain (Phakamile *et al.*, 2007). Effect of Mycotoxins on animal health and production shown in Table 3 according to Sarah and Vickers (2016).

Table 3. Effect of mycotoxins on animal health and production

Type of Mycotoxins	Causal agent	Symptoms	Effect
Aflatoxins (AFL)	*Aspergillus* spp.	Jaundice, Weight loss, Depression, Immunosuppression, Reduced milk yield	Carcinogenic, Partially broken down by the rumen and excreted in milk
Fumonisins (FUM)	*Fusarium* spp.	Decreased feed intake Reduced milk yield	Incompletely degraded by the rumen
Ochratoxin A (OTA)	*Aspergillus* *Penicillium*	Ill thrift	Potential human carcinogen metabolized by rumen Found in meat, milk and dairy products
Deoxynivalenol (DON)	*Fusarium* spp.	Immunosuppression Decreased feed intake Decreased milk yield	Commonly detected in maize Contamination usually occurs during crop growth when *Fusarium* grows best
T-2/HT-2	*Fusarium* spp.	Immunosuppression Reduced fertility	Members of the same family as DON and affect animals in a similar way Commonly detected in oats and oat feed Signs of exposure seen at lower levels of contamination than DON
Zearalenone (ZEN)	*Fusarium* spp.	Reduced fertility	Rarely toxic to ruminants Can be detected alongside its metabolites in urine

Prevention and treatment of mycotoxins

Desired level of mycotoxin in feeds and foods stuff is zero. But it is impossible in the environment. The Food & Agriculture Organization (FAO, 2001) provides a manual on application of hazard analysis and critical control points (HACCP) techniques for mycotoxin prevention and control. Management of mycotoxin in the cereal crops supply chain may be improved through preventing contamination and minimizing the toxicity of mycotoxins in feeds (Kabak *et al*., 2006). Pre-harvesting mycotoxin accumulation may be reduced by applying agronomic practices, minimizing plant stress and fungal invasion in the field. These includes proper irrigation, insect control, and pesticide application in some cases, cultivating resistant or adapted hybrids, tillage type, and proper fertilization, timely planting and avoiding delay harvesting. Fungicides have shown little efficacy in controlling pre-harvest aflatoxin contamination in corn, but may be helpful in the control of other mycotoxins. The application of fungicide within mold organism may reduce the mold growth and mycotoxicosis (Gareis and Ceynowa, 1994). A major success in reducing aflatoxins is the use of non-toxigenic fungi to competitively exclude toxigenic fungi. The best strategy for post-harvest control of mycotoxins is proper storage and handling of feedstuffs to prevent fungal growth. Management strategies also include mycotoxin analysis of feedstuffs, segregation of contaminated lots and treatments to reduce mold growth. Physical separation by cleaning or screening grains also helpful. Use of enzymes, like pancreatinase, carboxy-peptidase A, epoxidase and lactonohydrolase, potentially useful to mycotoxin degradation (Niderkorn *et al.*, 2007). Mycotoxin detoxification also applicable by potential use of microorganisms including *Flavobacterium aurantiacum* (aflatoxin), *Enterococcus faecium* (aflatoxin and patulin), *Eubacterium* : BSSH 797 and LS 100 (trichothecenes) and *Trichosporon mycotoxinivorans* (ZEA and OTA). Addition of 0.25-0.5% of calcium propionate in diets successfully detoxify the aflatoxin (Galvano *et al.*, 2001). Increasing nutrients such as protein, energy and antioxidant usually advisable for mycotoxin detoxification (Galvano *et al.*, 2001). Research has demonstrated that adsorbent materials such as silicate clays (bentonites and others), activated carbons or beta-glucan polymers (extracted from yeast cell wall) can reduce the effects of mycotoxins (Diaz *et. al.*, 2004). An in vitro gastrointestinal model is proposed for better simulation in vivo conditions and has been used to assess the mycotoxin binding efficacy by using some feed additives and mycotoxin binders (Avantaggiato *et al.*, 2004; Ali and Hasan, 2018). According to scientific report entitled "A review of mycotoxin-detoxifying agents used as feed additives: Mode of action, efficacy and feed/food safety" (EC, 2009), it was noted that inorganic absorbing agents (charcoal) seem to be effective for preventing adverse effects of many toxic agents. Organic absorbing agents have the ability to stimulate the immune system. Proven detoxifying agents may benefit animal health and indirectly humans (EC, 2007).

Conclusion

The presence of mycotoxins in the food/feed chain is an unavoidable and serious problem throughout the world. Practicing good sanitary measures, build up awareness about the toxic effects of mycotoxin in humans and livestock is urgent. Wide gaps exist on the toxicological effects of mycotoxin-contaminated feeds in animal. Research has been necessity in this field. Feed analysis is required to check mycotoxin contamination in impoted animal feeds stuff. Emphasis should be done on to develop new low-cost mycotoxin detection kit, which are portable, reliable, and easy to handle at field level.

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