THE PROBLEM OF MYCOTOXINS IN FEEDSTUFFS

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1. Introduction

The economic losses in the livestock industry due to mycotoxin contamination of the feed supply has been estimated in the millions of dollars (Jones et al. 1994). In 1985 the Food and Agriculture Organization (FAO) of the United Nations estimated that 25% of the world's grain supply is contaminated with mycotoxins annually (Mannion and Blaney, 1985). It is apparent that molds and mycotoxins represent a serious hazard to abundant yields of high quality grain, animal productivity and health, and to food safety from a human health perspective (Miller and Trenholm, 1994).

Mycotoxins are produced by actively growing molds. They are filamentous fungi and as with bacteria, molds grow logarithmically during their vegetative growth stage. Because of their rapid growth and depletion of available nutrients, new spores are formed for propagation of the species and there is production of some low molecular weight biochemicals, some of which prove toxic in animal species and are, therefore, named mycotoxins. Some molds produce several toxic metabolites while others produce only one. For example, the most widely known mycotoxin, aflatoxin, is produced only by Aspergillus flavus and A. parasiticus.

The term "mycotoxin" is derived from myco meaning fungi and toxin meaning toxicant of biological origin. Molds grow on a wide range of agricultural commodities including cereals, nuts, and a number of other crops. Molds reproduce by forming spores. Spores are carried by air currents and insects to other environments. Contamination of grain and other feedstuffs by mold is of utmost concern to the cattle and poultry industries.

2. Contamination of grain and feed

The major molds of concern are routinely found in soil. Airborne spores may enter the crop during the growing or silking stage. Fusarium enters as the plant seed germinates. Apparently, the water and sugar content of the plant usually prevents any serious mycotoxin formation after initial mold infection. Unfavorable weather or management conditions allows the viable mold spores to germinate, grow, and reproduce in feedstuffs in the field when conditions are suitable. Damage to the seed coat (pericarp) of corn and other feedstuffs induced by insects and stress as well as other factors (Table 1) may favor fungal invasion. As molds colonize on grains, they begin using the nutrients for their metabolism and propagation, which lowers the nutritional content of the grain. Bartov (1985) reported a 52 to 57% reduction in the fat content of contaminated corn after 50 d in storage.

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Table 1. Suggested Factors that Affect Mycotoxin Problems

High temperatures	Drought	Hail
Plant variety	Planting density	Soil texture
Mechanical harvesting	Soil fertility	Planting date
Rain during harvest	Continuous croping	Frost

3. Sampling feed for analysis

It is important to understand that mycotoxin contamination is not evenly distributed or homogenous in a given field, truck load or storage bin. Even between adjacent fields, heads of grain. or within a field, mycotoxin may be absent from a vast majority of the grain and very concentrated in a small percentage of the grain. Levels of 500,000 ppm can be detected in a single kernel of corn. For this reason, the sampling technique becomes critical when one seeks a meaningful test for a mycotoxin. Sampling requires drawing several small samples and compositing these and mixing thoroughly before pulling your final sample.

4. Mycotoxins of greatest concern

There are over 350 different mycotoxins that have been identified as being present in nature. Chemistries differ widely, with most classes of mycotoxins bearing little similarity to one another. Mycotoxins may be found in most any feedstuff, forage or grain, although some feedstuffs may be more prone to mycotoxin problems.

The formation and presence of mycotoxins in nature appears to be a growing global problem. The nature of the problem varies since some mycotoxins grow more readily in certain geographical areas (warm vs cooler climates) than others. Economically in the United States, the most commonly reported mycotoxins are aflatoxin, deoxynivalenol (DON or vomitoxin), zearalenone and T-2 toxin. Also, ochratoxin A and the recently discoved fumonisins have been noted in North America.

Aflatoxins - Aflatoxins are the most studied group of mycotoxins. Aflatoxin producing strains of Aspergillus are distributed worldwide in soil and air. When conditions are favorable and substrate is accessible as a nutrient source, colonization and mold growth may occur. Mold growth occurs more rapidly when moisture content is above 14% and temperature at 77°F or greater.

Aflatoxins are toxic and carcinogenic. Calves are more susceptable than older animals. Chronic aflatoxicosis is characterized by unthriftiness, reduced performance, anorexia, prolapse of the rectum and liver damage. Aflatoxins are absorbed from the gastrointestinal tract, extensively metabolized, and largely excreted. Even so, the distribution of the metabolites to various body locations of food animals can impart hazardous

residues to products used as food for man. Aflatoxins in the feed of an aminal are converted in part to a hydroxylated compound, termed aflatoxin M_1 (AFM_1), which appears in milk of lactating cows. The mean conversion ratio (1 to 2% of dietary intake) as reported in more current studies varies from about 58:1 to 75:1 (Frobish et al., 1986). The concentration of AFM_1 in milk disappears within a few milkings after the source of AFB_1 is removed from the diet. The present actionable FDA guidelines for AFM_1 in milk is 0.5 ppb and for AFB_1 in feed is 20 ppb.

Aflatoxins have had serious economic effects for livestock producers. Significant loses due to aflatoxicosis on individual cattle farms have been reported in the United States, Australia (Blaney and Williams, 1991), and throughout the world.

Zearalenone (F-2) - Pigs are very sensitive to the presence of zearalenone in the diet. The effects of zearalenone on ruminant animals is still somewhat unclear. Indications of increased reproductive problems due to the presence of zearalenone have not been well documented. Zearalenone elicits an estrogenic response in monogastrics (Sundlof and Strickland, 1986). Two studies (Weaver et al., 1986a, 1986b) have shown no estrogenic effects of pure zearalenone in dairy cows. In cattle and sheep clinical manifestations of zearalenone ingestion include: restlessness, diarrhea, udder enlargement, decreased milk yield, vaginitis, excessive vaginal discharge, continuous estrus, infertility, and abortion. It is suggested that zearalenone not exceed 250 ppb in the total dairy diet (Jones et al. 1994).

Deoxynivalenol (DON) - DON or vomitoxin has been associated with reduced feed intake and milk yield in ruminants (Trenholm et al., 1985 and Jones et al. 1994). Its presence (300 to 500 ppb) in feed indicates mycotoxin problems and perhaps it is serving as a marker for the presence of other mycotoxins. DON is produced by Fusarium species of fungi. Pigs are more sensitive to vomitoxin than poultry and other animals. In pigs, its presence has been associated with reduced feed intake, unthriftiness, reduced gains, decreased performance and vomiting. In a dairy study, Charmley et al.(1993) used 18 primiparous Holstein cows to study the effect of deoxynivalenol (DON) at three levels (0, 6 and 12 ppm of concentrate DM) on DMI and milk yield. The results are in Table 2.

Table 2. The effect of level of deoxynivalenol on dry matter intake and milk yield.

Item	Diet		
	DON-0	DON-6	DON-12
Total DMI (kg/d)	16.3	15.9	16.3
Concentrate intake (kg/d)	8.55	8.59	8.61
DON intake (mg/d)	.589	42.7	104.2
Milk yield (kg/d)	22.8	21.4	21.5

DON-6 = 6 ppm or 6 mg/kg.

The results in Table 2 showed no difference (P > .16) in the measured items in the 10 week study. No detectable amounts of DON occurred in milk. The results suggest that DON, per se, did not affect total milk production or DMI. The question that remains is whether or not DON would act the same in the presence of other mycotoxins in the feed supply.

T-2 Toxin - T-2 toxin is associated with gastroenteritis, intestinal hemorrhages (Petrie et al., 1977) and death in cattle. Also, there is a decrease in white blood cells and antibodies. Feed samples collected from problem herds in North Carolina showed that 5% contained T-2 toxins (>500 ppb). Residue studies suggest that about 0.2% of T-2 and its metabolites are excreted into milk. Cattle are more sensitive to T-2 toxin than vomitoxin.

Fumonisins - Fumonisins are a recently discovered group of mycotoxins primarily produced by Fusarium moniliforme. The toxin has been implicated in a variety of clinical syndromes in several species including equine leukoencephalomalacia (ELEM), porcine pulmonary edema (PPE), and toxic feed syndrome in poultry. ELEM is a fatal disease in horses, affecting the brain, liver and kidneys. Clinical signs include extended legs and neck, ataxia, paralysis, wobbly gait, and poor growth. Very little information is available on its toxicity to cattle.

5. Impact on health and the immune system

One of the main effects of aflatoxin is immunosuppression. Mycotoxins cause a wide variety of adverse clinical signs depending on the nature and concentration of mycotoxin present, duration of exposure, and the animal species, its age and nutritional and health status at the time of exposure to contaminated feed (Prelusky et al., 1994). Overt toxicosis, morbidity and death occur infrequently with most economic losses being due to subtle non-specific effects associated with reduced animal performance and increased disease incidence (Thompson, 1991).

Most mycotoxins appear to have the capacity to alter one or more significant functions of the host's immune system. For this reason, a combination of low levels of mycotoxins in the diet over an extended period of time could have a serious impact on animal health. The extent of impairment caused to the immune system by the presence of mycotoxins in the diet makes the animal more susceptible to disease and stress.

6. Prevention and Control Methods

It is important that producers, nutritionist and veterinarians understand the nature of molds and mycotoxins and how to apply the available strategies and technologies to circumvent their adverse actions.

Storage of feed commodities without good management practices may enhance mold growth since mold spores are already present. Store good quality grains at less than 14% moisture since moisture and oxygen are needed for spore germination (14.5 to 15.5%) and mold growth (13.5 to 14%) to occur. While in storage, feeds must be either dry, oxygen free, fermented or treated with a mold inhibiting chemical. Maintain a routine cleaning program for all feed-related equipment and storage and handling facilities.

In silage crops, the application of good management practices during harvesting and feeding is important. This involves: 1) harvesting the crop at the right moisture content to assure rapid fermentation, 2) filling the silo at a rapid rate, 3) packing tight to exclude oxygen and 4) covering. Silage preservatives may be useful to enhance fermentation. Proper removal and feeding of the silage from the silo will help minimize secondary fermentation that may occur when loosened silage is exposed to the air over periods of 6 to 10 hours, especially in summer. Good feed bunk management will prevent moldy feed from accumulating in the trough.

Adding selected absorbents to the ration such as bentonite, Novasil, Diabond and more recently Mycosorb may help spare adverse results in a dairy herd when aflatoxin is the minor contaminant and possibly other mycotoxins are present.

7. Mycosorb, the newest absorbent

Mycosorb differs from the clay absorbents in that it is a mannanoligosaccharide that is derived from yeast cells. Mannose sugars in the mannanoligosaccharides influence the immune system by stimulating the secretion of mannose-binding protein from the liver which binds to the capsule of invading bacteria and triggers the complement fixation system. Trenholm et al. (1994) conducted an <u>in vitro</u> experiment in which Mycosorb was found to bind zearalenone up to 80%. Mahesh and Devegowda (1996) compared the value of Novasil and Mycosorb to bind aflatoxin in contaminated feed. At the highest level of inclusion, both products bound aflatoxin at about 80% in the contaminated feed (Table 3) whereas at the lower level of inclusion Mycosorb bound aflatoxin to a greater extent than Novasil.

Table 3. Comparative ability of Novasil and Mycosorb to bind aflatoxin in contaminated feed in vitro.

	Novasil (%)			Mycosorb (%)		
Aflatoxin (ppb)	0.1	0.2	0.4	0.025	0.05	0.125
50	8*	26	54	33	58	83
100	14	47	78	48	58	69
200	25	65	78	51	62	79

*Values are percent aflatoxin bound.

Mannanoligosaccharides provide new insights into counteracting several pathogens and toxins besides their major impact on modifying the immune response. When using mycosorb in the ration, note that the droppings do not become more firm as frequently observed when using clay materials. The reason is due to the nature of the product. Mycosorb is a carbohydrate and the sugar used in the process allows mycosorb to bind pathogens and mycotoxins in the gut without affecting the good bacteria. The recommended rate of feeding is 10 gms daily/cow.

There are several advantages in using mycosorb over the clay absorbents. It does not bind nutrients such as vitamins and amino acids, a smaller amount can be used in the ration and mycosorb is the only absorbent that binds deoxynivalenol.

7. Summary and Suggestions

1. Mycotoxin contamination appears to be a growing economic problem for the livestock and feed industries.

2. The presence of mycotoxins in the crop lowers quality, yield and may cause problems in the animals exposed to these toxins. The risks of harm to animals from mycotoxins increase as exposure time increases.

3. While prevention is the primary goal, certain environmental conditions during planting and harvesting may be unavoidable.

4. In practical feeding situations it is rare to find a single mycotoxin. Rather, multiple mycotoxins at low to moderate levels are the norm and produce symptoms or disease patterns often distinctly different from those associated with the individual mycotoxin.

5. Purchasing clean feedstuffs is an important practice but this is not always possible. Obtain an analysis of the feedstuff or forage, especially feedstuffs that appear suspect. Do not feed any feed that appears to be moldy, including silage.

6. Treatments such as the use of Mycosorb or other binding agents may become more common in feeding programs. Make sure the absorbent selected is effective for the mycotoxin in question. In some cases, absorbents tend to bind other micronutrients such as vitamins and amino acids and may be ineffective against the toxin causing the problem.

7. The State Regulatory Agency and Milk Cooperative routinely check milk received from producers for the presence of aflatoxin M_1 (AFM_1). Aflatoxin B_1 (AFB_1) ingested by the cow is metabolized in the body and appears in milk as AFM_1. The transfer ratio is about 60:1. By FDA standards, milk must be below 0.5 ppb. It is suggested that the Regulatory Agency and others notify dairymen about their milk when even a trace of AFM_1 is found rather than waiting until the sample contains 0.5 ppb.

Selected References

1. Bartov, I. 1985. Comparative effects of antifungal compounds on the nutritional value of diets containing moldy corn for broiler chicks. Poult. Sci. 64:1236.

2. Blaney, B.J. and K.C. Williams. 1991. Effective use in livestock feeds of moldy and weather-damaged grain containing mycotoxins - case histories and economic assessments pertaining to pig and poultry industries of Queenland. J. Agric. Res. 42:993.

3. Charmley, E., H.L. Trenholm, B.K. Thompson, D. Vudathala, J.W.G. Nicholson, D.B. Prelusky, and L.L. Charmley. 1993. Influence of level of Deoxynivalenol in the diet of dairy cows on feed intake, milk production, and its composition. J. Dairy Sci. 76:3580.

4. Doerr, J.A. 1995. Mycotoxins in commercial livestock operations: Science and Solutions. Agrarian Marketing Corporation, Morristown, IN.

5. Frobish, R.A., D.B. Bradley, D.D. Wagner, P.E. Long-Bradley, and H. Hairston. 1986. Aflatoxin residues in milk of dairy cows after ingestion of naturally contaminated grain. J. Food Protection. 49:781.

6. Harris, B. Jr., and C.R. Staples. 1992. The problem of mycotoxins in dairy cattle rations. DS 31, Univ of Fl.

7. Jones, T.J., M.B. Genter, W.M. Hagler, J.A. Hansen, B.A. Mowrey, M.H. Poors and L.W. Whitlow. 1994. Understanding and coping with effects of mycotoxins in livestock feed and forage. AG-523, NC State Univ., Raleigh, NC.

8. Mahesh, B.K. and G. Devegowda. 1996. Ability of aflatoxin binders to bind aflatoxin in contaminated poultry feeds - an in vitro study. In:Proc.XX, World's Poultry Congress, New Delhi, India. 4:296.

9. Mannion, P.F., and B.J. Blaney. 1985. Fungi down on the farm. New Scientist. 105(1446): 12-16.

10. Miller, J.D. and H.L. Trenholm. 1994. In: Mycotoxins in Grain: Compounds other than aflatoxin. J.D. Miller and H.L. Trenholm (Eds), Egan Press, St. Paul, MN, 552.

11. Petrie, L, J. Robb and A.F. Stewart. 1977. The identification of T-2 toxin and its association with a hemorrhagic syndrome in cattle. Vet. Rec. 101:326.

12. Prelusky, D.B., B.A. Rotter and R.G. rotter. 1994. Toxicology of mycotoxins. In: Mycotoxins in Grain, compounds Other than Afl. J.D. Miller, H.L. Trenholm. (Eds) Eagan Press, Ma, USA, 359.

13. Sundlof, S.F. and C. Strickland. 1986. Zearalenone and zearalenol: Potential residue problems in livestock. Vet. Hum. Toxicol. 28:242.

14. Thompson, L.J. 1991. Fusarium mycotoxins and animal effects. In: Plant Pathology Extender. Fusarium Molds and Mycotoxins Associated with Corn. G.C. Bergstrom, L.J. Thompson (Eds) Plant Pathology Extension Report 91-1, Cornell Cooperative Extension, Ithaca, NY, 2.

15. Trenholm, L., B. Stewart, L. Underhill and D. Prelusky. 1994. Ability of grain gard to bind zearelenone and vomitoxin in vitro. 10th annual Symposium on Biotechnology in the Feed Industry. Alltech Inc., Nicholasville, KY, USA.

16. Trenholm, H.L., B.K. Thompson, K.E. Hartin, R. Greenholgh and A.J. McAllister. 1985. Ingestion of vomitoxin (deoxynivalenol) contaminated wheat by nonlactating dairy cows. J. Dairy Sci. 68:1000.

17. Weaver, G.A., H.J. Kutz, J.C. Behrens, T.S. Robison, B.E. Seguin, F.Y. Bates and C.J. Mirocha. 1986. Effect of zearalenone on the fertility of virgin dairy heifers. Am. J. Vet. Res. 47:1395.

18. Weaver, G.A., H.J. Kurtz, J.C. Behrens, T.S. Robison, B.E. Seguin, F.Y. Bates and C.J. Mirocha. 1986. Effect of zearalenone on dairy cows. Am. J. Vet. Res. 47:1826.

19. Whitlow, L.W., and W.M. Hagler, Jr. 1992. Nutrition related toxicities - mycotoxin contamination. In: Large Dairy Herd Management, Management Services, ADSA, Savoy, IL.