FEEDLOT NUTRITION

Strategies for Feeding Mycotoxin and Mold Contaminated Grains to Cattle

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INTRODUCTION

Moldy grain may adversely affect cattle production due to nutrition effects, mycoses or mycotoxicoses. Mycosis is a disease state caused by the fungi themselves, and mycotoxicosis is a disease state caused by secondary metabolites of the fungi. Thus, the mold itself may cause production losses separate and apart from any toxin effects. In fact, various molds have been associated with adverse health effects in plants, animals or humans. In many clinical cases reported it is difficult to separate effects of mycoses from those of mycotoxicoses. Producers generally suspect that mycotoxins are the main culprits for reduced feed intake, diarrhea, abortions, reduced gain or death of their livestock. The objective of this update is to review the current state of knowledge about effects of molds on nutrient content of feeds and mycotoxins (vomitoxin and zearalenone) on ruminant animal performance and health. Additionally, a section to devise recommendations on handling and feeding mold-contaminated grain is provided.

EFFECTS OF MOLD CONTAMINATION ON NUTRITIVE VALUE OF FEEDS

Molds need moisture (relative humidity over 70%), oxygen (minimum 1 to 2% O2), time and the correct temperature (variable according to species; high temperature promotes *Aspergillus*, low temperatures promote *Fusarium*) to grow (Diekman and Green, 1992). Mold growth may occur on grain in the field, in storage or in the feed bunk. Weather conditions may affect mold growth on crops in the field. Grains are normally kept dry to prevent mold growth in storage. Molds that infest crops in the field may be different from those which proliferate in storage or in the feed bunk.

Most livestock feeds have mold spores on them. Spore counts of less than 10,000 colony forming units per gram (cfu/g) are commonly found on grain. Mold becomes visible at approximately 1,000,000 cfu/g. When conditions are optimal for molds to colonize grains in the field or in storage, their first effect is utilization of nutrients for their metabolism and propagation. This results in decreased nutritional value of feeds. Energy, crude protein and crude fat values of moldy corn were decreased 5, 7 and 63%, respectively (Summers and Leeson, 1975, reported by Tindall, 1983).

Dietary fat is affected more extensively than proteins or carbohydrates. Dietary fat decreased 37 to 40% after 25 d or 52 to 57% after 50 d of storage (Bartov, 1985). Additionally, reduced production may occur due to the disequilibrium of rumen microflora which results after ingesting mold contaminated feedstuffs. Many molds produce substances with antibiotic activity. An alteration of rumen microflora after ingestion of moldy feed may be anticipated. Therefore, recommendations have been made to discount the nutrient value of grain by 5 to 10% if it contains 1 to 5 million cfu/g (M. Murphy, personal communication). However, mold counts alone do not identify the type of mold present.

All moldy grain does not contain mycotoxins, because toxigenic species must survive competition with nontoxigenic species for growth. Molds that produce toxins are referred to as toxigenic molds. Toxigenic molds commonly isolated from grains and forages in the Upper Midwest are: *Aspergillus sp, Fusarium sp* and *Penicillium* sp. Nontoxigenic molds include: *Absidia sp, Acromoniella sp, Alternaria sp, Cephalosporium sp, Chaetomium sp, Cladosporium sp, Epicoccum sp, Helminthosporium sp, Mucor sp, Nigrospora sp, Phoma sp, Scopulariopsis sp*, and *Trichoderma sp*. Both toxigenic and nontoxigenic molds may be associated with mycoses in cattle.

Mycoses are recognized in both animals and humans. Respiratory distress is perhaps the most widely recognized adverse health effect from mold spores. People handling excessively moldy grain are advised to wear masks to prevent sneezing, coughing and shortness of breath. These problems may occur because of direct physical irritation of inhaled mold spores or allergic reactions. Although similar diseases have not been specifically reported in cattle, the potential respiratory effects of mold spore inhalation in cattle should be considered when reduced dry matter intake or respiratory problems associated with feed are observed. Molds rarely cause systemic disease. But, mycotic abortions and septicemias have been reported in cattle.

In summary, the potential effect of grains with greater than 1 million mold cfu/g on the lungs, rumen fermentation, reproductive function, nutrient intake and production should be considered before pointing to mycotoxins as a cause of production losses.

MYCOTOXIN PRODUCTION

Hundreds of mycotoxins have been identified by researchers around the world. Strains of fungi isolated from one region of the world may produce different mycotoxins or mycotoxin amounts than those isolated from other regions. Toxigenic molds most commonly isolated from grains in the Upper Midwest are: *Aspergillus sp, Penicillium sp* and *Fusarium sp*. *Aspergillus sp* produce aflatoxin; *Penicillium sp* produce penicillic acid and patulin and *Fusarium sp* mainly produce deoxynivalenol (DON; vomitoxin) and zearalenone (ZEN; F-2 toxin). Aflatoxin rarely occurs in grains in the Midwest.

Aflatoxin production occurs in corn during drought conditions. However, aflatoxin may affect Upper Midwest cattle producers in any year if they are purchasing cotton or peanut seed products. Penicillic acid and patulin have not been associated with adverse health effects in cattle in the Upper Midwest.

Wet and cool weather conditions favors growth of *Fusarium sp* molds on crops in Upper Midwest fields. *Fusarium sp* molds cause head blight in small grains and stalk rot in corn. Head or kernel blight in wheat or barley is caused by *Fusarium graminearum*. The disease is commonly referred to as "scab" in either grain. Scab is most prevalent when *F. graminearum* spores on the anthers of blooming grain germinate after rainfall. Mold growth is then associated with the variety of grain, temperature, and moisture. Temperatures of 21˚C (70˚F or less) and relative humidity over 70% are ideal for *Fusarium* growth. The prevalence of infestation and severity of *Fusarium* growth are both associated with the number of days of rain during the bloom stage of grain growth.

F. graminearum may produce mycotoxins as it grows. Strains of *F. graminearum* have been shown to produce DON, ZEN, butenalide, T-2 toxin, diacetoxyscirpenol (DAS), nivalenol or moniliformin. From these, DON, T-2 toxin, DAS and nivalenol belong in the group of trichothecene mycotoxins (Trenholm et al., 1986). These are grouped according to their solubility in organic solvents. Group A including T-2 toxin, HT-2 toxin, neosolaniol and DAS are soluble in most aprotic solvents such as ethyl acetate and diethyl ether. Group B including scirpentriol, DON and nivalenol are highly hydroxylated trichothecenes soluble in very polar solvents such as methanol and ethanol (Trenholm et al., 1986). Group B appears to be less toxic than A. Trichothecenes grouped in A tend to be more potent skin-necrotizing agents, show more antiprotozoal activity, produce greater inhibition of protein synthesis and greater emetic activity (Trenholm et al., 1986). Although not totally conclusive for all species, toxins of group B such as DON may not pose the same health hazard as comparable levels of A. Compared to T-2 toxin and HT-2 toxin (at same levels), DON is a much less toxic substance.

Strains of *F. graminearum* isolated from North America have rarely produced anything but DON and/or ZEN, and then only a small percentage of samples contained levels considered toxic (Table 1). Zearalenone has been shown to react with the estrogen receptor to induce estrogenic effects in a wide variety of laboratory and domesticated animals (Diekman and Green, 1992).

The impacts of mycotoxins on animal agriculture are commonly measured in terms of the economics of animal production and safety of the food products produced. Vomitoxin ingestion has been associated with adverse health effects in animals and humans. Experimental studies have been conducted in swine, chickens, sheep and cattle. Swine are the species most sensitive to DON toxicity. Reduced intake and weight gain are reported in swine after ingestion of feeds containing 2 to 4 mg DON/kg DM (Bergsjo et al., 1992). Emesis is reported in swine ingesting finished rations containing greater than 10 mg DON/kg DM (Young et al., 1983).

Experimental studies with DON-contaminated grains have been conducted in broilers and layers. Adverse production effects were not observed in broilers and layers ingesting feed contaminated with up to 5 mg DON/kg diet DM for 168 d (Trenholm et al., 1984). Effects on hen egg production, egg weight, feed efficiency, fertility, or chick weights at hatching were not detected in layers ingesting feed containing 18 mg DON/kg diet DM (Kubena et al., 1987).

Table 1. Incidence of mycotoxin contamination in various U.S. surveys.

Mycotoxin	Year	Grain	Samples: Total	Samples: Positive	$\bar{x}$, ppm	Comment
Aflatoxin[a]	89-92	Corn	644	328	NA[b]	224 samples <20 ppb
Aflatoxin[a]	89-92	Cottonseed	106	44	NA[b]	20 samples <20 ppb
Deoxynivalenol[c]	82-83	Various	627	627	1.95	From .1 to 41.6 ppm
Deoxynivalenol[a]	1991	Winter wheat	207	201	2.4	From .4 to 40 ppm
Deoxynivalenol[a]	1991	Spring wheat	206	120	.9	From .9 to 7.6 ppm
Ochratoxin[a]	89-92	Various	168	0.0	0.0	----
Zearalenone[c]	82-83	Various	79	79	.93	From .05 to 10 ppm
Zearalenone[a]	89-92	Various	161	13	NA[b]	12 samples <.15 ppm

[a] Price et al., 1993.
[b] Not available.
[c] Reynolds et al., 1983.

PREVALENCE

The 1993, and potentially 1994, Minnesota wheat and barley growing seasons have been characterized as cool and wet. These conditions led to scab formation in the field. The result has been a high incidence of DON contamination in wheat and barley destined for malting and baking. All varieties of barley and wheat tested in 1993 had mean DON concentrations over 2 ppm (R. Jones, personal communication). For farmers attempting to market these grains for human consumption, these results are quite disappointing. Grain products for direct human consumption should not contain more than 1 ppm DON.

Because of the presence of rumen microorganisms, ruminants may be less sensitive to dietary DON concentrations than monogastrics, especially swine. Therefore, alternative uses for grains contaminated with DON beyond levels permitted for human consumption may be found as feed ingredients for ruminant animals. Additionally, results from these and earlier surveys (Reynolds et al., 1983; Price et al., 1993) indicate that DON concentrations beyond advisory levels for dairy or beef cattle occur in only 2 to 18% of the samples surveyed. Similar results were reported for other toxins. No ochratoxin was found in interstate traffic surveillance for 168 samples (45% corn) between 1989 and 1992 (Price et al., 1993). Also, of 161 samples tested for ZEN during the same period, 92% were negative, and 12 samples contained only between .07 and .15 ppm ZEN.

VOMITOXIN EFFECTS ON FEEDLOT CATTLE AND SHEEP

Experiments conducted with cattle and sheep also indicate that effects of DON on animal health or performance are negligible. Sheep fed wheat diets containing 8.5 mg DON/kg DM for 45 d had similar feed intakes, average daily gains and feed efficiencies as sheep fed no DON in a corn-based diet (Table 2; DeHaan et al., 1984). In another study, sheep were fed 15.6 mg DON/kg diet DM for 28 d with no apparent effects on dry matter intake, average daily gain or feed efficiency (Table 2; Harvey et al., 1986).

DeHaan et al. (1984) also evaluated effects of DON ingestion on feedlot steer and heifer performance. Cattle were fed diets containing 50% wheat (clean or scabby) to provide 0 or 1 mg DON/kg diet DM for a 142-d finishing period. No deleterious effects were observed on average daily gain, feed intake or feed efficiency (Table 2). In a more extensive study, Nelson et al. (1984) evaluated effects of feeding wheat diets containing 2.3 or 10 mg DON/kg DM or a corn-based diet containing .2 mg DON/kg DM on health, feedlot performance, and carcass characteristics of steers and heifers. Feeding 2.3 or 10 mg DON/kg diet DM had no adverse effect on intake, average daily gain, feed efficiency (Table 2) or carcass characteristics.

Table 2. Effects of deoxynivalenol (vomitoxin) administration on production performance of feedlot cattle and sheep.

	Dose						
Species	mg/kg diet DM	mg/d[a]	Duration, d	DMI, kg/d	ADG, kg	FTG[b]	Reference
Cattle	0	0	142	8.51	1.15	7.1	DeHaan et al., 1984
Cattle	1.0	8.6	142	8.65	1.16	7.1	DeHaan et al., 1984
Cattle	.2[c]	1.9	126	9.41	1.54	6.2	Nelson et al., 1984
Cattle	2.3	20.1	126	8.73	1.64	5.6	Nelson et al., 1984
Cattle	10.0	78.2	126	7.82	1.34	5.7	Nelson et al., 1984
Sheep	0[c]	0	45	1.27	.250	5.0	DeHaan et al., 1984
Sheep	8.5	11.6	45	1.36	.209	6.7	DeHaan et al., 1984
Sheep	0	0	28	1.05	.221	4.7	Harvey et al., 1986
Sheep	15.6	16.0	28	1.03	.206	5.0	Harvey et al., 1986

[a] Calculated from reported intake and toxin concentration.

[b] kg feed DM/kg gain.

[c] Corn (control) vs wheat-based (treatment) diet.

Studies reported herein with diets containing DON and negative for other prevalent toxins indicate that up to 15 or 10 mg DON/kg diet DM were tolerated by sheep and cattle, respectively, without any adverse effects on animal health or performance. A recent study conducted at the University of Minnesota at Morris confirmed these findings. One hundred eighty 415-kg crossbred steers were fed diets containing 75% barley (0 or 22 mg DON/kg DM) of similar test weights to provide 0, 6, 12 or 18 mg DON/kg diet DM (Table 3; DiCostanzo et al., unpublished data). Data were analyzed separately for the initial 28 d, or for the remainder of the 138-d finishing period. Feeding diets containing as much as 18 mg DON/kg did not affect intake, average daily gain, feed efficiency or carcass characteristics. Serum biochemistry or hematologic variables were not affected. Analyses are under way to determine DON residue in rib, liver and kidney samples obtained from a subset of 24 steers slaughtered immediately, or 21 d after withdrawal from their DON-contaminated diets. Therefore, taking into consideration results from the previous and this study, it is apparent that feedlot cattle may consume up to 18 mg DON/kg diet DM without any apparent effects on animal health or performance, when no other prevalent toxins are present in significant concentrations.

Only one study reported diarrhea in steers fed diets containing 14.5 mg DON/kg and 4.5 mg T-2 toxin/kg in the literature (Schuh and Baumgartner, 1989). Whether this effect was caused by DON, T- 2 toxin, the interaction of the two toxins, or other factors is not clear from the report, but it highlights the potential synergism that may occur when more than one toxin is present in feed.

Table 3. Effects of feeding vomitoxin-contaminated barley on feedlot performance of steers.[a]

	Deoxynivalenol, mg/kg diet DM				
Item	0	6	12	18	SE
Initial BW, kg	418	418	409	417	--
Final BW, kg	588	576	568	584	6.29
ADG, kg					
First 28 d	1.14	1.07	1.16	1.11	.06
Total	1.24	1.15	1.15	1.21	.04
DMI, kg/d					
First 28 d	10.58	10.45	10.52	10.52	.08
Total	10.96	10.60	10.59	10.60	.16
Feed DM/kg gain, kg					
First 28 d	9.69	10.16	8.82	9.51	.28
Total	9.01	9.31	8.95	8.78	.18

[a] DiCostanzo et al. (unpublished).

ZEARALENONE EFFECTS ON REPRODUCTIVE PERFORMANCE

Sheep

Sheep dosed with the equivalent of 12 mg ZEN/kg diet DM (24 mg/d) fed for 10 d prior to introduction of the ram caused prolonged estrous behavior, reduced ovulation rate and reduced fertility (Table 4; Smith et al., 1986). Twelve mg ZEN/kg diet DM is a dose rate considerably higher than those occurring naturally (Smith et al., 1991; Price et al., 1993). However, ZEN may exert its toxic effects by accumulating in the body, or as a result of short-term exposure to high doses. For instance, reduced ovulation rate was evident in ewes exposed to the equivalent of 1.5 mg ZEN/kg diet DM (3 mg/d) for only 10 d premating, while ovulation rate was reduced in ewes exposed to only .5 mg ZEN/kg diet DM equivalent (l mg/d) for 20 to 40 d premating (Smith et al., 1991).

There were no effects of ZEN ingestion on embryo survival or lambing performance after feeding 12 mg ZEN/kg diet DM (25 mg/d) for 10 d immediately postmating (Smith et al., 1991). However, ZEN intake during other stages of the reproductive cycle, or for long-term feeding, has not been studied. Smith et al. (1991) hypothesized that although effects of short-term exposure to ZEN are reversible, long-term exposure may not be.7

Apparently, only ewes are affected by ZEN when dosed prior to mating. Rams fed 2.5 mg ZEN/kg diet DM (6 mg/d) for 30 d had normal semen production and fertility (Smith et al., 1991).

Cattle

Effects of ZEN on reproductive performance of cattle are not clearly defined. Studies reported (Table 4) were based on doses considered in the high range of naturally occurring contamination (Price et al., 1993). Therefore, these data are presented to indicate the potential toxicity of ZEN, but not to infer about concentrations that potentially may be fed to cattle. Nevertheless, up to 100 mg ZEN/kg diet DM were dosed to either dry or lactating dairy cows for 42 d with no adverse physiological effects (Mirocha et al., 1978; Weaver et al., 1986a), although swollen genitalia were observed (Mirocha et al., 1978). However, there is a report from Austria (Schuh, 1983) where a clinical case of ZEN effects on reproduction of dairy cows was reported at a concentration of 1.25 mg/kg diet DM. No other facts were provided to aid in explaining this observation.

Table 4. Effects of zearalenone ingestion on reproductive performance of cattle and sheep.

Species	Type	Dose: mg/kg diet DM	Dose: mg/d	Duration, d	Effects	Reference
Bovine	Dairy heifer	15[a]	250	63	Reduced conception rate	Weaver et al., 1986b
Bovine	Dairy herd	1.25	NA[b]	NA[b]	Reduced conception rate	Schuh, 1983
Bovine	Dry dairy cow	26.0[a]	500	42	No histologic or physiologic effects	Weaver et al., 1986a
Bovine	Lactating dairy cow	25-100	NA[b]	42	Swollen genitalia, but normal estrous cycles and ovulation	Mirocha et al., 1978
Ovine	Ram	2.5[a]	6	30	No effects on semen production or fertility	Smith et al., 1991
Ovine	Ewes-postmating	12[a]	24	10	No effects on embryo survival or lambing performance	Smith et al., 1991
Ovine	Ewes-premating	.5[a]	1	20-40	Reduced ovulation rate	Smith et al., 1991
Ovine	Ewes-premating	1.5[a]	3	10	Reduced ovulation rate	Smith et al., 1991
Ovine	Ewes-premating	12.5[a]	25	10	Prolonged estrus behavior, reduced ovulation rate, reduced fertility	Smith et al., 1986

[a] Calculated from daily dose.
[b] Not available.

Heifers fed the equivalent of 15 mg ZEN/kg diet DM (260 mg/d) for 63 d had reduced conception rates (Weaver et al., 1986b). Therefore, Osweiler (1982) recommended that no more than 5 mg ZEN/kg diet DM be fed to virgin heifers. Fortunately, ZEN concentration in 161 samples analyzed8 between 1989 and 1992 across the U.S. ranged from nondetectable (148 samples) to between .07 and .15 mg ZEN/kg DM (12 samples; Price et al., 1993). The effect of phytoestrogens from other feed sources should always be considered when unusual estrogenic signs are observed.

SUMMARY OF MYCOTOXIN EFFECTS

Vomitoxin

From the aforementioned discussion on effects of deoxynivalenol (vomitoxin) on ruminant animal performance and health, it is safe to establish that feedlot cattle and sheep may consume diets containing up to 18 mg DON/kg DM without any adverse effects on health or performance. Studies evaluating DON and its metabolite accumulation in tissues are under way to establish whether these dietary concentrations may create a food residue concern. These findings should permit grain producers facing DON contamination to seek alternative ways to market their grains; as animal feed.

Zearalenone

Sufficient information has been generated with sheep to recommend that breeding ewes should not be exposed to more than 1 mg ZEN/d (approximately .5 mg ZEN/kg diet DM) for more than 20 d prior to ram introduction. Higher levels cause infertility in even shorter exposure periods. Rams, or pregnant ewes, are resistant to higher dietary concentrations, but these are not well defined. For cattle, a recommendation in the literature indicated not to exceed 5 mg ZEN/kg diet DM for growing heifers prior to their first breeding. This recommendation seems reasonable, because heifers fed 250 mg ZEN/d (equivalent to a dietary concentration of 15 mg ZEN/kg diet DM as determined from observed feed intake in the study) had reduced ovulation rate. Reported effects of ZEN on production and reproduction of mature cows were not sufficiently consistent to suggest acceptable levels. However, cows may be more resistant to ZEN toxicosis than heifers.

FEEDING AND MANAGEMENT STRATEGIES

The Food and Drug Administration has issued advisory levels for DON (vomitoxin) in flour for human consumption and animal feeds. Adverse animal and human health effects are not expected to occur at these advisory levels. Flour for direct human consumption should not exceed 1 ppm DON. Grain or grain byproducts to be used in swine rations should not exceed 5 ppm with the added recommendation that these ingredients not exceed 20% of their diet. Grain or grain byproducts to be used in ruminating beef cattle and feedlot cattle older than 4 mo and for chicken rations should not exceed 10 ppm with the added recommendation that these ingredients not exceed 50% of their diet. Grain or grain byproducts to be used in rations for all other animals should not exceed 5 ppm with the added recommendation that these ingredients not exceed 40% of their diet.

The following is a recommendation chart to highlight strategies for dealing with mold and mycotoxin contaminated grains:

When To Test	
Field conditions	Stalk rot or ear rot in corn Scab in wheat or barley
Grain conditions	Low bushel weight Visible mold, musty odor
Animal conditions	Reduced dry matter intake Respiratory distress, diarrhea Reduced production

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What To Test For	
Moisture/dry matter	Indicator of mold growth conditions
Crude protein, crude fat	Indicator of mold growth activity
Starch	To evaluate effects of mold activity when formulating high production diets
NDF, ADF	May increase when mold utilizes energy in grain
Ash	Indicator of mold activity
Mold count	Discount energy and protein value when >1,000,000
Mycotoxins	When any of the "when to test" conditions are present

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Management	
Mycoses	Use feed commodities with low spore aerosilation potential Blend with better quality feedstuffs at feeding
Mycotoxicoses	Blend to acceptable nontoxic concentration at feeding, except for aflatoxin-contaminated commodities Use of clay, bentonite and aluminosilicates has reduced effects of aflatoxin in monogastrics

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