Mold and Mycotoxin Problems in Livestock Feeding

This article explores effects of mycotoxins on animals, testing feeds for toxins, dealing with contaminated feeds, and limiting mycotoxin production.

Introduction

Weather conditions during growing and harvesting seasons may appreciably increase the incidence and degree of moldy feed and mycotoxin problems from year to year. Cool, wet growing seasons may delay grain maturity, especially for corn, and result in mold and mycotoxin formation in the field. Fusarium toxins are more likely to occur under cool, wet conditions during growth, harvesting, and storage. Hot, humid conditions favor the development of aflatoxins. Delaying harvest to increase maturity and reduce moisture levels, or to avoid muddy field conditions, may result in increased mold growth and mycotoxin formation. Storing grains, feedstuffs, and forages at moisture levels beyond recommended ranges or in poor storage units also may increase mold-related problems. Recent knowledge indicates that these problems sometimes may be the cause of previously unexplained production and health problems. Mycotoxins may be present in feeds that have little or no obvious mold present.

Moldy Feed Effects

Moldy or musty feed won't always contain dangerous mold poisons or mycotoxins, but the presence of considerable mold in itself may adversely affect production and health. Digestibility of the ration may be decreased sufficiently to reduce energy content by 5% for ruminants. Thus, it is best to discount energy values (book values or estimates via testing) by multiplying them by 0.95 when feeds have appreciable mold. Such feed is also less palatable and may lower the intake of energy, dry matter, and critical nutrients. This may considerably reduce milk production, growth or weight gains, and depress resistance to metabolic and infectious diseases.

Reductions in production performance and increases in health problems from moldy feed are often moderate if mycotoxins are not present. For example, a 5 to 10% drop in performance may be typical with mold infestation, whereas mycotoxin contamination leads to greater losses in production, even when mold is not readily apparent.

More problems with mycotic abortions and respiratory disorders may result when a considerable amount of moldy feed is used. This may happen due to a high content of mold and mold spores in the air or in the ingested feed. (Farmer's lung is a disease that may affect humans in a heavily mold-infested environment.) The placenta of aborted fetuses should be examined for the distinct signs present in most mycotic abortions.

Sometimes mold spores are counted on moldy feeds to obtain an indication of the extent of molding and relative risks in feeding them. Table 1 contains classification of risks at various mold spore counts. These counts may be obtained from some laboratories at $10 to $20 per sample. Since some moldy feeds may not contain an elevated spore count for a variety of reasons, spore counts sometimes underestimate the degree of mold present and potential risks involved.

Table 1. Feeding Risks a at Various Mold Spore Counts b

Mold Spore Count per Gram	Feeding Risks and Cautions
Air-dried c	
Under 500,000	Relatively low count
1/2 to 1 million	Relatively safe
1 to 2 million	Discount energy (x 0.95) Feed with caution

2 to 3 million	Closely observe animals and performance Discount energy (x 0.95)
3 to 5 million	Dilute with other feeds Discount energy (x 0.95) Observe closely
Over 5 million	Discontinue feeding

a Risks refer primarily to effects of mold per se without regard to possible mycotoxin content. Depressed digestibility, feed intakes, and performance may occur from a high mold content without mycotoxins present. Harmful mycotoxins may be present even when there is little or no obvious mold content. b Mold spore counts sometimes may underestimate degree of mold present, especially in feeds that have been ensiled for some weeks. Observe and record relative amounts of mold present. c Dry feeds such as grains, concentrates, and hay at a usual 85 to 93% dry matter content. Know the dry matter content before submitting samples and find out on what basis counts are reported. Adjust as received counts to a 90% dry matter or air-dried basis, as follows: 90% DM count = As received count ÷ (% DM as decimal ÷ 0.90) Example for corn with 70% DM and a spore count of 1.1 million as received: 90% DM count = 1,100,000 ÷ (0.7 ÷ 0.9) = 1,100,000 ÷ 0.778 = 1,413,882.

When air-dried grains at 10 to 16% moisture have low test weight (weigh less than standards per bushel), a decrease in energy content may occur as indicated in Table 2 for corn. If low test weight corn is moldy, the discount should be increased by 5% for ruminants, as shown.

Table 2. Recommended Factors for Adjustment of Energy Values for Corn Fed to Ruminants.

Test Wt., lb/bu	Adjustment Factor a for Non-Moldy Feed	Adjustment Factor a for Moldy Feed
54	1.000	0.950
50	0.987	0.937
45	0.971	0.921
40	0.955	0.905
35	0.940	0.890

a Based on Minnesota digestibility trials in which normal corn was fed to sheep. Moldy corn discount (5%) is based on Penn State sheep trials and those at several other stations. Adjusted NE value = Book or Tested Value x Factor. Example: NE_L (via test) for shelled corn (0.90 Mcal/lb DM) adjusted for mold content at 45-lb test wt. = 0.90 x 0.921 = 0.829 (0.83).

Appreciable heating in a feed is an indication that molds and bacterial growth, as well as nutrient losses, may be occurring. Heating also depresses feed intake and makes animals more susceptible to digestive upsets.

Mycotoxin Effects

Under some conditions, molds may produce potent mycotoxins at levels that may adversely affect animal production and health. As detailed in the *Interpretation of Test Reports* section of this article, there also is a potential public health concern when milk or other human foods contain a level of aflatoxin that exceeds maximums established by the Food and Drug Administration (FDA). While moderate effects may appear initially, more obvious reductions in performance often result within a few days to several weeks of ingestion of the contaminated feed or ration.

Milk production may drop by more than 15%. Young animals nursing an infected dam may do poorly due to appreciable aflatoxin in her milk. Off-feed, ketosis or acetonemia, and displaced abomasum (DA) problems may rise sharply. Some animals may have diarrhea or show signs of hemorrhaging. Marked estrogenic effects such as swollen vulvas and nipples or rectal and vaginal prolapse may occur when some mycotoxins are present. Abortion or a reduction in conception or litter size may even result.

The following section contains information on effects that have occurred from ingestion of diets containing various levels of some mycotoxins. Some effects may occur at levels lower than those indicated, since lower concentrations may not have been researched or were not encountered in documented field cases. Higher intakes might be necessary in other cases, since the mycotoxin indicated may have been only one of several which were not identified through testing. Symptoms or clinical indications of appreciable liver or kidney damage may occur, increasing the likelihood that mycotoxicity is the causative factor. Such damage often occurs at high or prolonged intakes of mycotoxins.

Mycotoxin Effects on Livestock Performance and Health

Aflatoxin (B1, B2, G1, G2, M1, M2)

General

- Young, immature animals are more susceptible and may be affected when nursing a dam whose diet contains over 20 to 40 ppb in the total ration dry matter (TRDM). Limit TRDM to 20 to 40 ppb for cattle under 200 lb and pigs under 3 to 4 weeks. The liver is the primary organ affected. Sometimes hemorrhage and paralysis occur. Disease resistance is depressed by aflatoxins.

Swine

- Reduced growth and feed efficiency, liver damage in pigs less than 117 days at 170 to 280 ppb in TRDM. Liver damage, reduced performance and some deaths at 400 to mostly 600+ ppb in TRDM.

Cattle

- Levels in milk will exceed the legal maximum of 0.5 ppb within 4 to 6 days on diets with over 40 to 50 ppb in TRDM. Levels fall in 2 to 4 days on a low aflatoxin diet. Reduced growth and feed efficiency in cattle under 300 lb at 150 to 200 ppb in TRDM. Reduced growth, feed efficiency and sometimes liver damage in cattle over 300 lb at 220 to mostly 400 + ppb in TRDM.
- No effects in dairy cows at 300 to 380 ppb in TRDM. Moderate reduction in milk at 600+ ppb in TRDM.
- Pronounced drop in milk (50%) and sharp decrease in feed intake at 2,400+ ppb in TRDM. Reduction in rumen motility at 400 ppb in TRDM.
- Deaths in young cattle at 600+ ppb in TRDM and in adults at 1,000 to mostly 2000 + ppb in TRDM.

Horses

- Possible lack of muscular control, excitability, circling, tetany, deaths from unspecified levels.

Zearalenone (or F2 toxin)

Swine

- Enlarged vulva, prolapsed uterus or rectum, enlarged nipples or mammary glands, vulvovaginitis, enlarged prepuce at 0.8 to 4 ppm in TRDM.

Cattle

- Enlarged vulva and possible irregular heats and infertility at 4 to 7 ppm in TRDM. No abortions noted in most cases. No effects on performance at 0.5 ppm in corn or about 0.15 ppm in TRDM.

DON (Deoxynivalenol or Vomitoxin)

Swine

- Feed refusals, reduced growth, weight loss, sometimes diarrhea starting at 0.6 to 1.0 ppm in TRDM. Vomiting usually at 15 ppm or above. Sometimes infertility and deaths.

Cattle

- Off-feed, ketosis, displaced abomasum, pronounced milk decrease, sometimes diarrhea at 1.5 to 2.5 ppm in TRDM or possibly lower.

DAS (Diacetoxyscipernol)

Swine

- Estrogenic effects, infertility, poor gains, oral and gastroenteric necrosis and hemorrhage at 0.5 to 1.0 ppm in TRDM.

Cattle

- Effects similar to DON with DAS at 1.0 to 2.0 ppm in TRDM.

T-2

Swine

- Skin lesions, digestive tract inflammation, hemorrhage, feed refusal, possible infertility, vomiting, reduced milk at 1.0 to 2.0 ppm in TRDM.

Cattle

- Effects similar to DON plus hemorrhage at 1.0 to 2.0 ppm.

HT-2

Swine

- Weight loss, hemorrhage, diarrhea, possible infertility at 2.0 to 4.0 ppm or possibly less.

Cattle

- Effects similar to DON plus hemorrhage at 2.0 to 4.0 ppm or possibly less.

Ochratoxin

Swine

- Kidney and sometimes liver damage. Increased urine production and water intake. Reduced feed intake, weight loss, abortions, delayed sexual maturity. Sometimes deaths at 1.0 to 2.7 ppm in TRDM. Total feed refusal at 5 ppm in TRDM.

Cattle

- Kidney involvement, reduced feed intakes and performance, hunched stance in calves, possibly others. Apparently cattle are less sensitive than swine according to LD 50's.

Poultry

- Probably the most harmful mycotoxin for poultry.

Fumonisin (B1 toxin)

Horses

- Most susceptible species and apparently suffer more serious effects. Leukoencephalomalacia: signs within 7 to 30 plus days include depression, incoordination, weakness, blindness, head-pressing, and death from brain necrosis at levels of 8 to 10 ppm. Other species apparently are not seriously affected by fumonisin produced by *F. moniliforme* but are susceptible to zearalenone, DON, DAS, etc. also produced by it.

Slaframine

Cattle, sheep, horses

- Slobbering, salivation; sometimes diarrhea, increased urine production. Usually associated with legume intake.

Ergotism

Cattle, sheep, swine, horses

- Staggers, nervous, and motor disorders from some forms. More often lameness and tissue necrosis resulting in loss of ears, tail, feet; possible infertility and lactation failure in swine. Mainly from ergot present in quackgrass and other grasses. Dallisgrass and grains infected with a hard, black, banana-shaped growths on seed heads.

Fescue toxicosis

Cattle

- Reduced feed intake, decreased gains, milk production and reproduction. Sometimes lameness and loss of portions of feet and tails.

Horses

- Often abortion, stillborns, retained placenta, and reduced milk production.

The effects of mycotoxins accumulate over a period of time. The presence of more than one mycotoxin may increase these effects. Chronic effects are more often noted than acute, sudden ones. Often animals do not die or show acute signs early in a mycotoxicity. It may take several days to several weeks to cause marked changes in performance or acute symptoms. Aflatoxins are usually present at lower levels, and animals are not as sensitive to them.

Fusarium toxins, especially trichothecenes, are more likely to affect livestock. Trichothecenes include T-2, HT-2, deoxynivalenol (DON or vomitoxin), and diacetoxyscipernol (DAS). Zearalenone, another *Fusarium* toxin, is prevalent and more often occurs during storage than in the field. Fumonisin effects horses drastically and quickly after ingestion.

Mycotoxins may develop in almost any feedstuff during the growing season, at harvest, or during storage. Cool, wet weather favors *Fusarium* toxins, while hot, humid weather encourages aflatoxin formation. Thus *Fusarium* toxins are more prevalent in the Northeast and Midwest, while aflatoxins produced by *Aspergillus* are more common in the South. Feeds from several regions often are used on many farms, particularly in the grain-deficit areas of the Northeast and Southeast. While grains receive the most attention, byproduct feeds, protein concentrates, finished feeds, oilseeds, wet brewers grains, food wastes, and forages may also

contain mycotoxins. Whole-plant corn silage and haylage are more likely to be contaminated than dry hay. Heat-processing and ensiling do not destroy mycotoxins. It is important to note that signs of mycotoxicity mimic those of other metabolic and infectious diseases, including ketosis, Johnes, BVD, Salmonella, clostridial infections, and some poisonous weeds such as pigweed.

Many molds are capable of producing mycotoxins. However, black mold, often found in cobs and sometimes on kernels, is unlikely to produce mycotoxins. The fungus causing scab on small grains, however, may produce mycotoxins under favorable conditions.

Testing for Mycotoxins

When to Test

Testing for mycotoxins should be considered when signs of potential effects on performance and health exist and cannot be readily explained. This is particularly important when moldy feeds are being fed or when marked changes in production or health have occurred among a relatively large proportion of animals.

What to Sample

Sample all moldy and non-moldy feeds that are likely to contain mycotoxins. Start by testing total mixed rations (TMR) when these are used in feeding ruminants. Sample concentrate mixtures when they are used in conventional ruminant feeding or for single-stomached animals. If mycotoxins are found in the TMR or grain mixtures, ingredients within them should also be tested. Sample grain supplements and forages separately if fed conventionally.

Sampling Procedures

It is important to take representative samples since mycotoxins are present in such small quantities and may only occur in isolated spots in a bin or silo. The mycotoxin content is not necessarily related to the amount of mold seen. Care of samples before and during transit to a laboratory is important since some mycotoxins could develop at this time. Recommended procedures vary for wet and dry feeds. Wet feeds include TMR, silage, haylage, high-moisture grain, and other feeds with a moisture content over 15%. Dry feeds include finished concentrates, protein supplements, dry grain, hay, and other items with a moisture content under 12%.

Suggested sampling method #1 for dry feeds

1. Take 8 to 12 samples at each of 3 to 5 feedings or removals from storage.
2. Mix the sub-samples well, obtain a one-pound composite, and store it in a cool, dry place.
3. Combine 3 to 5 composites. Mix them well and prepare a one-pound sample for submission to a laboratory.
4. Keep an additional one-pound composite for possible confirmatory testing or for testing nutrients or toxic substances other than mycotoxins.

Suggested sampling method #2 for dry feeds

1. Take 12 to 20 stream samples from an entire delivery or 12 to 20 deep-probe samples from a bin, or sample cores of 12 to 20 different bales in a lot or mow of hay. Include probe or core samples from the edges of bins or storage units where mold is more likely to occur.
2. Place dry sub-composites and the final composite in a double thickness of either paper or cotton bags for storage and mailing. Store them in a cool, dry place.
3. Take or ship to a laboratory for arrival on Tuesday through Thursday. This prevents samples from sitting over the weekend.

Suggested sampling method for wet feeds

1. Obtain 8 to 12 sub-samples of wet feeds at each of at 3 to 5 feedings or removals from storage.
2. Mix sub-samples well and obtain a 1.5-pound composite sample.
3. Place composites in a thick plastic bag or double plastic bags. Pack composites tightly and force out excess air before sealing with a good closure tab.
4. Store samples in a freezer until a final composite is prepared.
5. Combine 1.5-pound composites and mix them well.
6. Prepare a final 2-pound composite to submit to a laboratory for mycotoxin testing.
7. Keep an additional 2-pound composite frozen for possible confirmatory mycotoxin or other testing.
8. Test a third composite for moisture at the farm or a feed testing laboratory to determine its dry matter content.

9. Store final composites in a freezer until sending them for testing.

10. Ship wet samples in a frozen state, packed in a heavy insulated bag containing a frozen ice pack(s).

11. Hand deliver or use overnight express mail for wet samples and ship for arrival on Tuesday through Thursday. Avoid holiday arrivals.

Remember to adequately identify all samples with an indelible marker. Follow the lab's instructions for sample identification, but at a minimum each container should typically include a sample number, a brief description of the feed, and the name of the person submitting it. Include an order form with each batch of samples requesting mycotoxin screening, but do not place the note inside sample bags since they may become unreadable due to moisture uptake.

In addition to the representative samples described in this section, you may also want to note the following suggestions:

- Since mycotoxins are sometimes not found in obviously moldy material, submit a sample taken from a moldy spot and its perimeter. Include one part moldy material and four parts non-moldy from its perimeter, 6 to 10 inches surrounding the moldy spot.
- Since most feed ingredients might contain mycotoxins and not all moldy feeds have them, it is best to sample at least all major ingredients. Total mycotoxin intakes must be considered in decision making.

Types of Tests

Basically, two major types of mycotoxin tests are available: quick tests and confirmatory or quantitative tests. Many laboratories doing confirmatory tests may initially run quick tests to determine whether the samples are positive and need further quantitative testing.

Costs for mycotoxin tests vary for both kinds of tests. Quick tests often range from $10 to $50 per sample. Confirmatory tests generally cost $75 to $150 per sample, depending upon methods used and the number of mycotoxins included in the scan. Confirmatory testing from some laboratories may require 5 to 10 days or more from submission until a report is received.

Quick Tests

Quick tests include immunoassays (i.e., ELISA tests) and thin-layer chromatography (TLC) testing. They are available from many commercial and public laboratories serving veterinarians and feed and premix concerns. These tests also may be purchased from suppliers for such laboratories and sometimes are run at feed mills, veterinary offices, and on some farms with sufficient need for them. Most quick or screening tests have been developed to detect specific mycotoxins. For example, aflatoxin kits or others for zearalenone or DON (vomitoxin) are available for quick or screening tests that may take only a few hours to one day for reading. Quick tests are more qualitative than quantitative in nature. For example, some are more accurate in the 0.5 to 1.5 ppm range for *Fusarium* mycotoxins, due to interfering substances. Thus, higher or lower values may be suspect until confirmed by the more quantitative confirmatory methods. In some cases, high values may be off by a factor of several times.

A scan of feed samples by a black light (long wave UV) is sometimes run as a quick test for acceptability of grain or other feeds. Since this test is subject to a lot of both false positives and false negatives, it should not be used as the single determining factor for whether or not feeds are safe for animal feeding or whether mycotoxins may be involved in animal performance or health problems. Black-light testing is a highly presumptive aflatoxin test because it indicates the presence of a fungal metabolite and possibly other substances--not mycotoxins. Use of the black light is more effective when all grains have been cracked and viewing is done by an experienced person who has perfect color vision to detect the bright greenish-yellow fluorescence indicative of possible mycotoxin contamination. This fluorescence, however, may diminish or disappear during storage. Thus other types of quick and confirmatory tests are recommended rather than the black light scan. Follow up black-light testing with other quick or confirmatory tests.

Confirmatory Tests

Confirmatory tests that may be more quantitative and possibly include more mycotoxins are usually run using high-pressure liquid chromatography (HPLC) or gas chromatography. They should be used when quick tests are strongly positive and when a scan for more mycotoxins is avail-able than from quick tests. Select reputable laboratories that test for a range of mycotoxins. Tests often are run for only three or four of the 200 or more mycotoxins that may exist. Consult several laboratories to determine what mycotoxins are being tested with both quick and confirmatory tests. Test for as many mycotoxins as feasible. A basic group for testing should include aflatoxin, zearalenone, deoxynivalenol (DON), T-2, and diacetoxyscipernol (DAS). If possible, obtain HT-2 and ochratoxin tests. Obtain a mycotoxin screen including fumonisin if serious problems occur with horses. To some extent, positives in the preferred basic group may indicate the possible presence of other non-tested mycotoxins.

Interpretation of Test Reports

It is important to note that many laboratories report values on an as-received basis and do not report dry matter levels in the samples to facilitate interpretation. Some do not indicate what basis is used in reporting. Thus, it is important to know if values are on an as-received or some other basis. If percent dry matter is not reported or mycotoxin levels are not given on a dry matter basis, it is essential to determine dry matter contents on all wet samples. Then levels may be calculated on a dry matter basis for interpretation. As-received or as-fed values may be converted to a dry matter (DM) basis as follows:

- DM Value = As-Received Value ÷ % DM as decimal

For example, a DON level of 1.0 ppm in whole plant corn silage containing 30% dry matter is equivalent to 1.0 ÷ 0.30 or 3.33 ppm on a DM basis. A level of 1.0 is only at a level of concern in the absence of symptoms, but a 3.33 puts the level on a DM basis into a potentially harmful category as shown in Table 3. If symptoms were present, the DM level would indicate the need to temporarily discontinue feeding or restricting the intakes of the silage in an attempt to alleviate the problems encountered. Most air-dried feeds contain 85% to 95% dry matter, but high-moisture grain may vary considerably in dry matter content and should be tested.

Another problem in reporting involves indiscriminate use of ppm (mg/kg) and ppb (mcg/kg) to designate mycotoxin content. Some laboratories report them both ways with no consistency. This sometimes causes confusion or errors in interpretation, since there is a 1,000-fold difference in these units. Preferably, aflatoxin levels should be reported as parts per billion (ppb), while other mycotoxins should be reported as parts per million (ppm).

It is important to look closely at the units given in results for each test and employ the proper units when interpreting levels. (Use information given in Table 3 or other guides.)

Levels may be converted for interpretation purposes as follows:

1. ppb to ppm: move decimal point three places to left Example: DON @ 1200 ppb is only 1.2 ppm
2. ppm to ppb: move decimal point three places to right Example: Aflatoxin @ 0.2 ppm is 200 ppb

Interpretation of mycotoxin content is complicated by several factors beyond problems with moisture-dry matter content and units used in reporting. The significance of the mycotoxin content of an individual feed in the diet depends upon how much is used in the ration and whether or not it or others may be present in other ration ingredients. The level present in the total ration dry matter (TRDM) is of prime importance. Also, the presence of several mycotoxins at relatively low levels may be associated with problems, since a combination of mycotoxins may potentiate or increase the harmful effects of contaminated feed. Further, very little data from controlled studies exist on what harmful effects may be expected at various levels of mycotoxin intake. Field experiences and surveys must be relied upon heavily. It also is possible that harmful effects noted may be caused by mycotoxins other than those tested or actually result from other factors including both metabolic and infectious diseases. Mycotoxin contents associated with sub-acute or less than dramatic effects on production, health, and reproduction are particularly lacking. There are many conflicting and confusing reports in the literature and in guides due to those factors, as well as factors such as problems in obtaining representative samples, proper handling of samples, inadequate scans for multiple toxins, and accuracy of the tests used. In many cases, reports only include mycotoxin levels in the grain or on a single feed used rather than levels on a total diet basis.

A guide for interpretation of mycotoxin tests in livestock feeding is presented in Table 3. Keep in mind the many complicating factors mentioned above. Also, consider the information on levels reported to be involved in certain problems such as those described previously. The guide in Table 3 is based upon the literature, and field experiences in dozens of farm problems. Read the footnotes carefully.

Table 3. Guide for interpretation of mycotoxin tests in livestock feeds.

Mycotoxin	Concern Level a	Potentially Harmful to Cattle b	Potentially Harmful to Swine b	Potentially Harmful to Horses b
Aflatoxin, ppb c				
Major ingredient				
Air-dried d	20	20 to 300	20 to 100	
Dry Matter	22	22 to 333	22 to 111	
TRDM e	20 to 40	20 to 132	20 to 102	
Zearalenone, ppm				
Major ingredient				

Air-dried	0.50	5.0 to 9.0	1.0 to 5.0	
Dry matter	0.56	5.6 to 10.0	1.1 to 5.6	
TRDM a	0.56	3.9 to 7.0	0.6 to 3.9	
DON/Deoxynivalenol, ppm				
Major ingredient				
Air-dried	0.50	4.5 to 11.0	0.7 to 1.3	
Dry matter	0.56	5.0 to 12.0	0.8 to 1.4	
TRDM	0.56	2.5 to 6.0	0.6 to 1.0	
DAS, ppm				
TRDM a	0.25	0.7 to 1.5	0.4 to 1.0	
T-2, ppm				
TRDM	0.25	0.7 to 1.5	0.7 to 1.5	
HT-2, ppm				
TRDM	0.25	1.5 to 3.0 f	1.5 to 3.0 f	
Ochratoxin, ppm				
TRDM d	0.25	5.0 to 9.0 f	0.7 to 1.5 f	
Fumonisin, ppm				
Major ingredient				
Air-dried	1.0 to 3.0	6.0 to 10.0	10.0	6.0 to 10.0
Dry matter	1.1 to 3.3	6.7 to 11.1	11.1	6.7 to 11.1

a Level indicating possible favorable conditions for mycotoxins and probable need for further testing of all feeds or the TMR. Pending further tests, negative samples should be considered at concern levels in the presence of moderate symptoms and at harmful levels with marked symptoms. Limit amounts fed if moderate performance effects are present. Discontinue use at least temporarily if pronounced performance effects or acute clinical symptoms are present. Closely observe animals and continue checking for other possible causes. b Mycotoxins at these levels indicate probable involvement in performance effects or acute clinical symptoms. Discontinue feeding at least temporarily in the presence of either type of symptoms. Observe animals closely in the absence of symptoms and do further testing of all feeds or the TMR. c See the text for important details on aflatoxins. A diet with 20 to 40 ppb aflatoxin should not be fed to dairy cows to keep milk values under FDA actionary levels and to avoid health or performance effects in young animals fed milk. d Air-dried refers to a dry matter range of 85% to 95% as normally found in most dry feedstuffs. e TRDM = total ration dry matter. f Crude estimates based on relative differences in LD 50s between chickens and livestock species. ppm = parts per million or mg/kg. ppb = parts per billion or mcg/kg. ppm to ppb: move decimal three places to right. ppb to ppm: move decimal three places to left.

A negative test with no symptoms in animals suggests that a mycotoxin problem is highly unlikely. However, a negative test in the presence of symptoms possibly related to mycotoxins indicates the need for further inspection of feeds, further testing of suspected and other feeds in the diet, and a continued search for other causative factors. If drastic or pronounced effects are present, suspected feeds should be discontinued or fed in limited amounts at least temporarily. Additional mycotoxin and possibly other tests should be performed on the ration, blood, and feces in an attempt to find other causative factors.

In the absence of symptoms, feeds with a mycotoxin content ranging from the minimum concern level to the lower potentially harmful level should be closely inspected, re-sampled, and re-tested since these levels indicate that conditions favoring mycotoxin production were present. In the presence of moderate effects on performance, re-sample and test the feeds as well as reduce intakes of positive feeds. In the presence of pronounced or drastic reductions in performance, discontinue the feed at least temporarily at levels of concern.

Feeds with mycotoxins at potentially harmful levels or higher should be fed at restricted levels in the absence of performance effects and discontinued at least temporarily if positive at concern levels in the presence of otherwise unexplained performance problems.

The levels of concern and potentially harmful effects given for aflatoxin require detailed explanation. Because aflatoxin is a carcinogen and may enter milk when it is present at certain levels in the diet, FDA regulates allowable contents in feed and food items, including milk. The maximum level of aflatoxin permitted in milk is 0.5 ppb, while other foods may contain up to 20 ppb. The relationship between diet and milk contents has been well-documented in research studies.

Approximately 0.91% of the aflatoxin in the diet may appear in milk. To be on the safe side, the total ration dry matter intake by dairy cows should not exceed 20 to 40 ppb. Further, the FDA has placed a maximum limit of 20 ppb on corn in interstate commerce, or that intended for unknown destinations for use in human foods or in feeding immature animals, including young poultry or lactating dairy animals. It is widely accepted that other grains, feed ingredients, and finished feeds also should contain levels of aflatoxin that meet the FDA regulations summarized below. Thus, the lower contents indicated in Table 3 as being potentially harmful are set at 20 ppb, while the higher levels given are those that may affect mature animals. Diets for animals nursing young or producing milk for consumption by humans or young animals preferably should not exceed 20 to 40 ppb aflatoxin because younger animals are more susceptible to toxicity. Consult the previous discussion for greater detail on aflatoxin contents, which have been incriminated in harmful effects. As yet, there are no known regulations on the content of mycotoxins other than aflatoxin in items intended for use in feeds or human foods. Note that FDA regulations allow for specified levels of aflatoxin over 20 ppb when corn is used for older animals, other than lactating dairy cows and poultry. State and Federal agencies spot-check milk, other foods, corn, other grains, and feeds for aflatoxin content.

Summary of FDA Regulations on Aflatoxin in Corn in Interstate Commerce or for Use at Unknown Destinations

- Corn with levels up to 20 ppb may be used in human foods and for all animals.
- Corn with levels over 20 ppb should not be used for immature animals including immature poultry and for lactating dairy animals.
- Corn with levels over 100 ppb should not be used for breeding cattle, breeding swine or mature poultry.
- Corn with levels over 100 ppb should not be used for finishing swine (e.g. 100 lb or greater).
- Corn with levels over 300 ppb should not be used for finishing (i.e. feedlot) beef cattle.

These levels are widely accepted as applicable to other feedstuffs, mixed feeds, and forages. No restrictions or regulations cover mycotoxins other than aflatoxin in the U.S.

Alleviation of Mold and Mycotoxin Problems

Action should be taken when signs of possible moldy feed or mycotoxin problems exist. Improvements in production, performance, and health often occur within three to seven days to several weeks after offending feeds are removed from the ration or their intakes severely reduced, and recommended feed additives are used to bind mycotoxins that may be present. Steps to take include the following:

1. Eliminate other possible causes as soon as feasible with the help of experienced nutritionists, veterinarians, and other trained consultants.

2. Properly adjust energy contents of any moldy feeds or lightweight grains in the ration. See previous text and Table 2.

3. Clean moldy grains and remove fines from whole grains suspected of having mycotoxins.

4. Include aluminosilicate or bentonite in the ration to reduce the effects of mycotoxins that might be present. These compounds may bind mycotoxins in the digestive tract and reduce their absorption. Use at a level of 0.1% in swine feeds and at 0.5% to 1% of the total ration dry matter in diets for ruminants. Aluminosilicate products include Novasil and Flo Bond. Bentonite products include sodium bentonite and Astra Ben-20. Aluminosilicates have reduced aflatoxin in milk by 25% to 44% and reduced effects on performance in various animals, including poultry. Aluminosilicates and some bentonites apparently have improved performance in *Fusarium* mycotoxicity in the field, although controlled research is somewhat lacking. Bentonites and aluminosilicates are available from feed suppliers at a modest cost. However, do not depend on these additives alone to fully restore performance and health or normal aflatoxin levels in milk.

5. Use a suitable mold inhibitor in dry feeds that contain 14% or more moisture. Sodium or calcium propionate or organic acids may be used at a level of 0.20% to 0.25% in non-ensiled feeds with 14 to 17% moisture. Use 0.5% to 0.6% in non-ensiled feeds with 18 to 24% moisture. See Table 4 for other information on acid treatment of high-moisture grains before storage. Other inhibitors including commercial products that have been cleared by FDA may be used according to the manufacturer's directions.

6. Test the ration or most of its components for mycotoxins. See section titled *Testing for Mycotoxins*.

7. Consider testing to help eliminate other possible causes of the adverse effects. Other tests on feed, disease testing via feces, blood, and possibly metabolic profiling may be necessary.

8. Discontinue or severely restrict use of obviously moldy feed or suspected non-moldy feed pending test reports. If moderate effects are noted, reduce intakes by 50% or more for at least one to three weeks. If minimum-use rates to avoid spoilage in ensiled items will not allow a 50% reduction, discontinue its use for at least one to three weeks. If marked or drastic effects on production performance or health are present, discontinue suspected feeds for at least one week. Improvements should be noted within three to seven days in most cases. A period of several weeks to several months may be necessary if serum enzyme or other clinical tests indicate that considerable liver or kidney damage has occurred.

9. If symptoms are present, discontinue or severely restrict use of feeds that test positive for mycotoxins especially those other than aflatoxin. If marked effects are present, discontinue items with a positive test. If moderate effects are present, reduce intakes by 50% or decrease levels in the total ration dry matter to those at minimum concern levels or lower. Reduce aflatoxin levels in total ration dry matter to those indicated as safe for milk production and those for various other animals as outlined by FDA.

10. Ammoniation may be used to destroy at least some of the aflatoxin present in feeds. Ammoniation is a delicate process that requires special equipment and safety precautions. It is best suited for treatment in volume by commercial concerns and is done primarily in areas consistently experiencing widespread mycotoxin contamination.

If animals do not respond favorably to a ration lower in mold and/or mycotoxin content and to the inclusion of aluminosilicate or bentonite, then other possible causative factors should be vigorously pursued. When animals respond favorably, problem feeds may be gradually reintroduced or increased in the ration in an attempt to find an intake that will not appreciably affect performance.

Often, only feeds in a certain portion of a bin or silo or in a given delivery cause problems. Sometimes discontinuing the use of a silage, haylage, or high-moisture ensiled grain and re-sealing the silo for several weeks may stop further formation of mold or mycotoxins. Thus, the feed may be used later to some extent after discarding the next 6 to 10 inches of material and any obviously moldy or spoiled feed. Animals a few weeks to several months of age are more susceptible to mold and mycotoxin problems. Likewise, animals close to parturition or in early lactation are more sensitive to mold and mycotoxins. Therefore, if contaminated feed must be used, feed it to older replacement cattle and dairy cows in late lactation.

Prevention of Mold-Related Problems

While it is impossible to prevent all problems, certain measures will greatly reduce the chance of serious effects on production performance and health. These include the following:

Consider your location

Grow hybrids and varieties of crops that are adapted to the zone in which the farm is located with respect to days-to-maturity and growing season.

Harvest according to recommended practices

Harvest crops as recommended, taking special care to store at proper moisture levels. Avoid damaging kernels or grain if it is to be stored in dry form. Also avoid fallen stalks.

Store properly

Clean and properly maintain storage units, particularly silos. Frequently check stored crops for signs of heating, molding, and other deterioration. Avoid storing grains and feedstuffs at moisture levels over 12 to 13%, since they are subject to mold and mycotoxin development. Guard against differentials in temperature between grain and outside air that may result in condensation on bin or silo walls and cause moisture migration that leads to molding. Store ear corn at 18 to 20% whole ear moisture only if in narrow cribs with good air movement. Use silage preservatives or additives when the ensiling process is at risk due to moisture levels that are below or above recommended range. Consider using preservatives or additives in the first and last 20% portions of the silo which are under more stress due to seepage, greater exposure, or less packing. Consider microbial additives when temperatures at harvest are unusually hot or cold or when grain has been partially heat-dried before ensiling.

Handle soft or immature grains wisely

Carefully consider harvesting and storage alternatives before choosing one. It is generally best to harvest corn as soon as weather prevents further maturation to avoid mold and other deterioration, large losses from storm-downed grain, and corn moisture levels or temperatures that increase risk at ensiling. Alternatives include the following:

Consider whole plant silage if it can be made at a minimum whole plant moisture content of 55 to 60%, and it can be fed on the farm or marketed.

Consider ensiled high-moisture grain if kernel or grain moisture is not under 22% or over 45%, and it can be fed on the farm or marketed. Use a microbial additive if ensiled high-moisture grain is ensiled at under 25% or over 35% moisture, or during cool weather with day time temperatures under 50 to 60°F. If acid preservatives are used, add a full-dose as indicated in Table 4 for non-silo storage. This is an option, especially for grain to be ensiled at moisture levels below 22%. Silos may range from properly-sized, high-moisture grain units to forage-sized, tower or horizontal units that are sufficiently narrow to enable a feeding rate of 2 to 3 inches daily in upright or 4 to 5 inches daily in horizontal units. Horizontal units should be 6 to 8 feet deep for adequate packing. Ag-Bag storage units also may be used if holes are patched when they occur. Grains, especially those with over 28% moisture, may have low test weight, and energy values may need discounting. See Table 2.

Table 4. Application rates for undiluted propionic acid in the preservation of high-moisture grains not stored in a silo.

Grain Moisture, %	Pounds of acid per ton of grain for 6-mo. Storage	Pounds of acid per ton of grain for 12-mo. Storage
25	12	15
30	16	20
35	17	25
40	20	30

Non-silo storage of high-moisture grain may be accomplished by placing acid-preserved grain in piles or non-metal bins. Use levels of organic acids as given in Table 4.

Grain drying is another option. Preferably, kernel or grain moisture should be under 35% for economical drying. Dry gradually by removing not over 8% moisture per hour. Remove less moisture per hour after grain reaches 19%. Avoid temperatures over 140°F for grain used in human foods or 180°F for animal feeding. Kernel temperatures should not exceed 110°F for seed use. Temper the dried corn before cooling and cool it gradually to air temperatures before storage, or aerate it during storage until grain temperature is equalized with outside air. Aerate with fans at an air flow rate of 1/10 cubic foot per minute per bushel.

Maintain clean equipment

Clean equipment used in harvesting, storage, and feeding immediately after each use.

Use extra caution with high-moisture grain

Do not allow grain with over 15% moisture to stand over six hours without being ensiled, acid treated, dried, or aerated while awaiting drying.

Limit exposure of stored feed

Prevent mycotoxin and mold problems in ensiled or other wet feeds by removing them from storage just prior to feeding. Use sufficient amounts of materials daily to limit heating and molding on exposed surfaces of silage. Increase feeding frequency if the material or a TMR containing it heats appreciably between feedings. Keep the face of horizontal silos well sheared. Only remove amounts that will be used at each feeding. Use silage brought from a different farm within 6 to 12 hours. Keep it in a tight pile with a substantial cover or tarp. Use wet brewer's grains within 5 to 7 days of delivery, unless they are ensiled in an Ag Bag or other unit. Keep piles tight and well covered to discourage mold and mycotoxin formation.

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Penn State College of Agricultural Sciences research and extension programs are funded in part by Pennsylvania counties, the Commonwealth of Pennsylvania, and the U.S. Department of Agriculture.

Where trade names appear, no discrimination is intended, and no endorsement by Penn State Extension is implied.

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Code: ART-1169