COOPERATIVE EXTENSION SERVICE
UNIVERSITY OF KENTUCKY • COLLEGE OF AGRICULTURE

Aflatoxins in Corn

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Aflatoxins, metabolites of the fungus *Aspergillus flavus*, are potent liver toxins and carcinogens in animals, and may also be human carcinogens. Although aflatoxin contamination in corn is uncommon in Kentucky, occasional incidents do occur and can create significant economic losses for individual producers. Of all the known *mycotoxins* (toxic substances produced by fungi), aflatoxins in corn and other commodities (milk, peanuts, or cottonmeal, for example) probably generate the most concern when they occur at high levels in marketing channels.

Preharvest aflatoxin contamination of corn is associated with drought and high temperatures during grain fill. Postharvest aflatoxin contamination can develop when grain is improperly managed through the drying and storage process.

Occurrence of Aflatoxins

Nationwide, aflatoxin contamination of high-quality corn is uncommon, particularly in corn grown in the Midwest and further north. Researchers at Purdue University conducted a five-year study of various mycotoxins in Indiana corn sampled at or near harvest. During the period 1989-1993, aflatoxin was detected in corn samples collected at harvest in only one year, and then only in two of the samples tested.

While aflatoxin contamination is very uncommon in midwestern corn, severe drought conditions during grain fill can favor aflatoxin contamination, creating concerns for marketing and utilizing corn. Following the 1988 drought, the incidence of corn lots in the Midwest with over 20 parts-per-billion (ppb) aflatoxins ranged from a low of 6% in one state to a high of 36% in another. However, even in the state with the highest incidence in 1988, the level of contamination varied greatly from field to field and farm to farm. Thus, regional and statewide generalizations about aflatoxin contamination in corn are difficult to make, even in years in which aflatoxin contamination is a concern.

Our limited survey data and general experience indicate that the incidence of aflatoxin contamination in Kentucky is similar to that of other midwestern states. Most years, aflatoxin contamination in the field is very uncommon, although it does sometimes occur when drought conditions prevail during grain fill. Furthermore, one or more cases of contamination occur most years when shelled corn is not promptly dried or properly stored.

Kernel Infection and Aflatoxin Formation

A. flavus survives between growing seasons in crop residue and in soil. Waste corn around storage bins can also be a source of spores. The fungus is nearly always present in corn production areas, although the level of infestation can vary.

Infection of silks by *A. flavus* occurs in the following manner. During hot, humid conditions microscopic spores are produced on corn residue and in survival bodies at the soil surface. These spores are carried by air movement, and some of them land on the silks. The spores germinate, and the fungus colonizes the silks if hot conditions continue. The fungus can then grow down the silk channel and around the developing ear. Yellow-brown silks that are still moist are most susceptible to colonization and invasion down the silk channel. Fresh, unpollinated silks are relatively resistant, and brown, dry silks can be colonized, but growth of the fungus down the silk channel is limited.

Once fungal growth is present under the husk, the fungus may infect uninjured kernels if the plant is stressed once the dough stage is reached. Drought and high temperature (80-110° F) during grain fill are by far the most common stress factors associated with preharvest aflatoxin contamination. High nighttime temperatures may be particularly important. Other factors that can enhance the risk of aflatoxin contamination include nitrogen deficiency, excessive plant populations, and poor root development.

Another means of infection is through wounds caused by birds and insects. Kernel injury from insects or birds provides infection sites that are easily colonized by the fungus. Certain insects can carry spores of *A. flavus* and introduce them onto senescing silks and into wounded kernels.

Even if kernels are uninfected at harvest, the presence of *A. flavus* spores on kernel surfaces sets the stage for postharvest contamination with aflatoxin. When temperature and moisture conditions permit, *A. flavus* spores can

germinate and infect injured or broken kernels within a day or two of harvest. Aflatoxin production by the fungus is most active at 81-86 F and is suppressed below 55 F and above 104-108 F. *A. flavus* can grow at higher or lower temperatures beyond those indicated here, but it does not produce aflatoxins. *A. flavus* can grow and produce aflatoxins (aflatoxin B_1 and B_2) in kernels at 17-18% moisture or higher. Aflatoxin B1 is usually present in higher concentration, and is of greater toxicological concern than B_2.

By late August, little can be done to reduce the risk of **preharvest contamination** of corn with aflatoxins. However, proper drying and storage are key to minimizing the risk of **postharvest aflatoxin contamination.** The conservative approach is to assume that a harvested crop is contaminated with spores of *A. flavus*, and handle it in ways that minimize the risk of aflatoxin development. General guidelines are to harvest corn early with minimum kernel damage, dry and cool it without delay, aerate it regularly, and monitor it closely during storage. Proper storage conditions are the best insurance against mycotoxin accumulation in storage.

Sampling Corn for Testing

Producers frequently are frustrated at the great variability in testing corn for aflatoxin. This is a common frustration, as research has shown repeatedly that there is a great deal of statistical variability in aflatoxin analyses for several agricultural commodities.

An illustration of this variability is evident in data published for peanuts. (Similar results have been found for corn, but this peanut example provides the raw data, which tell the story nicely for our purposes.) For several lots of peanuts, ten separate samples were properly collected, processed, and analyzed for aflatoxins. Concentrations in parts-per-billion (ppb) are given in Table 1 for the ten samples in each of three representative lots.

Within each lot, different samples gave different results. Which result is a producer to believe? This is the major challenge of any analysis: How can a person test a small sample and make a conclusion about an entire lot, such as a truckload of corn?

Aflatoxin tests are inherently variable for several reasons. One reason is that contaminated kernels are usually not uniformly distributed in a load, so one sample might contain a probeful from a hotspot while the next sample does not. We are also testing for toxins that are dangerous at the level of parts-per-*billion*, which is an extremely low level. To put it in perspective, one part-per-billion is equivalent to one second in 32 years.

Typically there is a great deal of statistical variability in detecting a compound at this extremely low level, whether it is an aflatoxin or any other compound. Considering that one kernel can have as high as 50,000 ppb, and that 40 of these highly contaminated kernels in a bushel of corn would be enough to put the bushel at the 20 ppb action level, what is the likelihood of reaching into that bushel of corn and collecting one of these kernels on the first try? So the results on a particular sample will depend on how many contaminated kernels were present in the sample, and on how high the level of contamination was in those kernels. Just by sheer chance, this varies each time a sample is taken. Also, different laboratories sometimes provide results that differ somewhat when testing for aflatoxins in samples provided under the auspices of the American Association of Cereal Chemists.

Table 1. Aflatoxin test results (parts-per-billion, ppb) in ten samples collected from each of three peanut lots (arranged in ascending order for ease of interpretation).

Sample	Lot A	Lot B	Lot C
1	0 ppb	0	0
2	0	0	3
3	0	0	5
4	0	0	19
5	2	0	32
6	4	3	49
7	8	8	87
8	14	26	91
9	28	52	127
10	43	70	168
Average	**9.9**	**15.9**	**58.1**

One cannot escape some variability in testing for aflatoxins. So it is important to recognize that great sampling variability exists, and to use methods that minimize this variability.

The most important thing is to take a representative sample. Sample shelled corn using a grain probe, or grab fistfuls from a moving stream. Don't collect a sample just from the most convenient place, like the top of the truck or storage bin. The odds are good that this will give a misleading result.

Take at least ten probefuls and collect at least 10 lb of corn. The corn must be below 16% moisture unless the test is being performed immediately. Test results from high-moisture corn may not be accurate if the test is delayed, as the fungus can continue to grow and produce aflatoxins. Grind the sample and mix it well before drawing a small subsample for testing. The AOAC International (formerly the Association of Official Analytical Chemists) requires that the entire 10-lb sample be coarsely ground to pass through a No. 14 sieve and mixed, and that a 2- to 4-lb subsample be ground to pass through a No. 20 sieve (about the consistency of fine instant coffee), before aflatoxin testing in the laboratory.

After collecting a sample of shelled corn, recognize that aflatoxin can still accumulate if the sample is held under warm, moist conditions. Storage or shipment of the sample at a moisture content below 13% essentially prevents the continued development of aflatoxin.

Be aware that variability exists from one sample to the next, even if the samples were collected properly and the

lab is completely reputable. If you have a problem load, collect and test several samples separately, and average the results. The average of several samples gives a much better estimate of aflatoxin concentration than one sample, even one very large sample.

Detection of Aflatoxins

Several methods are used to detect aflatoxins in corn. Examining the kernels for yellow-green fluorescence under a blacklight is commonly used as a quick preliminary test. The entire sample should be cracked or coarse-ground for blacklight testing. The fluorescing material actually is kojic acid, not aflatoxins. Thus, yellow-green fluorescence under a blacklight does not indicate the presence of aflatoxins. Fluorescence simply indicates that aflatoxins *may be present* in the kernel. A blacklight test can often give a "false positive"; that is, a positive result from a clean load of corn. A similar glow under blacklight may be produced by tips of corn kernels, corn beeswings (glumes), soybean hulls, certain weed seeds, and strains of *A. flavus* that do not produce aflatoxins. It is also possible to get a "false negative"; that is, a negative blacklight result from a contaminated sample. Thus, the blacklight can be used as a first screen but positive findings require further testing before concluding the lot is contaminated with aflatoxins.

Commercially available rapid test kits (such as the Agri-Screen kit) generally provide good results **if stored and used properly**. Be sure to pay careful attention to kit directions. Several kits provide test results within minutes which indicate whether the sample is above or below some critical value, such as 20 ppb total aflatoxins. Others provide a numerical test result, indicating how much aflatoxin is present in the sample. Several kits are certified by the USDA Federal Grain Inspection Service and approved by the AOAC International.

Testing by an independent analytical lab is sometimes the best approach, although this can be time-consuming and sometimes costly. Corn samples should only be sent to laboratories that participate in an independent reference sample program for aflatoxins, to ensure accuracy of the test results. Contact your county Extension agent for information on laboratories offering services for aflatoxin analysis.

Laboratory analyses that provide a measure of total fungal populations in the grain (expressed as CFU's or colony-forming-units) do not provide an indication of the level of mycotoxin contamination in the grain.

FDA Action Levels

Aflatoxins are the only mycotoxins currently regulated by the U.S. Food and Drug Administration (FDA). The FDA has established action levels which prohibit the use of a contaminated lot from interstate commerce (Table 2).

Table 2. U.S. Food and Drug Administration guidelines for acceptable levels of total aflatoxins in food and feed.

Action level (ppb)	Commodity	Species
0.5 (aflatoxin M_1)[a]	Milk	Humans
20.0	Any food except milk	Humans
20.0	Feed	All species
Exceptions		
100.0	Corn	Breeding cattle, breeding swine, and mature poultry
200.0	Corn	Finishing swine (>100 lbs.)
300.0	Corn	Finishing beef cattle
300.0	Cottonseed meal used in feed	All species

[a]Specifically for aflatoxin M_1, a toxic metabolite of aflatoxin B_1, that occurs in milk.

Clinical Effects

Fungal toxins produce a wide range of clinical effects in animals. The economic impact of reduced productivity, increased incidence of disease because of immune suppression, subtle but chronic damage to vital organs and tissues, and interference with reproductive capacity is many times greater than that of acute livestock death.

Aflatoxins cause liver damage, decreased milk and egg production, and suppression of immunity in animals consuming low dietary concentrations. Nursing animals may be affected by exposure to aflatoxin metabolites secreted in the milk. While the young of a species are most susceptible to aflatoxins, all ages can be affected. Clinical signs include gastrointestinal dysfunction, reduced reproductive function, decreased feed consumption and efficiency, anemia, and jaundice.

Dairy

Of the over 200 mycotoxins identified, aflatoxins are the ones of major concern to dairy producers. When aflatoxins are consumed by lactating cows, they not only can be toxic to the cow but also can appear in the milk within 24 hours. Aflatoxin levels in milk are regulated by the U.S. Food and Drug Administration as a probable human carcinogen. Therefore, dairy producers must be careful about the use of feeds that may contain aflatoxins, particularly corn and cottonseed.

While ruminant animals such as dairy cows are more resistant to aflatoxins than nonruminants, toxicity does occur with disastrous results. Chronic exposure to aflatoxins has caused decreased breeding herd efficiency, birth of

smaller and unhealthy calves, diarrhea, acute mastitis, respiratory disorder, prolapsed rectum, hair loss, and reduced feed consumption. Calves are particularly sensitive with reduced growth rate and kidney damage. The liver and kidney are the major organs damaged by aflatoxins. Aflatoxins can be especially damaging to the liver with noticeable reductions in milk production and appetite.

Beef Cattle and Sheep

Acute aflatoxicosis in cattle consists of reduced feed consumption, dramatic drops in milk production, weight loss, and liver damage. Aflatoxins have been shown to affect rumen function by decreasing cellulose digestion, volatile fatty acid formation, proteolysis, and rumen mobility. However, chronic exposure of beef and dairy cattle to naturally occurring levels of aflatoxins may have an even greater economic impact as a result of reduced feed efficiency, immunosuppression, and reduced reproductivity.

In general, ruminants are able to tolerate higher levels of aflatoxins and longer periods of low-level intake than simple-stomached animals. The response of ruminants to aflatoxin-contaminated feed depends upon the level of toxin present, age, and species. Young, rapidly growing ruminants are more susceptible than are mature animals.

Swine

Aflatoxin toxicity has been reported in suckling pigs, growing and finishing swine, and breeding stock. Clinical and pathological signs include decreased growth rate, poor efficiency of feed utilization, toxic hepatitis, nephrosis, and systemic hemorrhages. Aflatoxins can be transferred in utero from sows to piglets and can affect the biological and immunological response of the neonatal pig. The effects of aflatoxins in pigs are varied depending on the age of animal, diet, level of toxin, and length of exposure. Problems from aflatoxins appear to be most severe in younger pigs. Aflatoxins are absorbed rapidly from the gastrointestinal tract and concentrate in the liver and kidney. Chronic aflatoxin intake impairs the pigs' resistance and immune system resulting in more infectious disease problems.

Horses

Clinical signs of aflatoxicosis in horses include reduced feed intake, rapid weight loss, lethargy, lack of muscular control, circling, tetany and even death. As with other species, target organs appear to be the liver and kidneys. Horses on a high plane of nutrition seem to be better able to tolerate aflatoxin toxicity in corn.

Poultry

Aflatoxins have produced severe economic losses in the poultry industry, affecting ducklings, broilers, layers, turkeys and quail. While it takes high levels to cause mortality, very low levels are detrimental if fed continuously. Clinical signs of aflatoxicosis include anorexia, decreased weight gains, decreased egg production, hemorrhaging, embryo toxicity, and increased susceptibility to environmental and microbial stressors. Aflatoxins can cause a decrease in the activity of several enzymes needed for the digestion of starches, proteins, lipids, and nucleic acids. The decreased activities of these enzymes could contribute to the malabsorption of nutrients associated with aflatoxicosis.

Reducing Risk of Aflatoxin Contamination

Aflatoxin contamination of corn is rare under most growing conditions in Kentucky. Sound production, harvest, and storage practices can reduce the risk of aflatoxin contamination even further. In a year where numerous lots are found to be contaminated, even lots of corn that otherwise qualify as U.S. No. 1 can have excessive aflatoxin contamination, although lots receiving a lower grade do run a higher risk of contamination.

Production Practices

Preharvest aflatoxin contamination of corn is typically associated with heat/drought stress during grain fill and injury to kernels. Thus, production practices to minimize these factors will reduce the risk of preharvest aflatoxin contamination.

Be sure the hybrids sown are adapted to local climatic and soil conditions, and avoid excessive plant populations. Consult with your county Extension agent or seed supplier when deciding on planting density. Maintain adequate levels of nitrogen for good growth. Implement sound management programs for insects that can damage kernels, such as the corn earworm, European corn borer, and fall armyworm. If the soil is compacted, subsoiling can alleviate stress and reduce the risk of aflatoxin contamination.

Pre-Harvest Chores

Clean out all harvesting, handling, and drying equipment and storage bins prior to harvest. Remove all broken corn, dust, and foreign material, which can provide a source of contamination. Always remember to provide adequate dust protection to those who work around grain handling equipment. Mow around storage bins to discourage insect/rodent activity. Also, remove spilled grain from under bin doorways and near grain transfer points.

Check all combine settings before harvest and again as harvest progresses through changes in grain moisture and field conditions. Combine adjustments play a big role in the level of grain damage and, consequently, in the ability of molds and insects to attack stored grain. Closely monitor the number of broken kernels in the combine tank during

harvest to determine if other machine adjustments are needed. Damaged corn is more susceptible to mold growth and aflatoxin contamination than undamaged corn, should temperature and moisture conditions favorable for fungal growth develop after harvest.

Harvest should begin soon after the crop matures if adequate dryer capacity is available. Delaying harvest usually increases losses from field-borne diseases, insects, birds, and weather. Given the current prices for corn and drying fuel, the best moisture level to start harvest is between 25 and 27 percent, provided it can be dried to 16% moisture content or less within a day or two.

Drying

Shelled corn should be dried to 15.5% or below within 24-48 hours of harvest, to minimize the risk of mold growth and mycotoxin contamination. Natural air and low-temperature drying systems do not always achieve this when corn moisture exceeds 18% and are generally not recommended above this level.

Most grain drying systems are bin dryers, column dryers, or a combination of the two types. Each system uses different combinations of airflow and drying air temperature, which restricts both drying capacity and grain moisture at harvest. Table 3 gives suggested operating conditions for corn drying systems in Kentucky. Check corn moisture and temperature frequently before and after drying to avoid environmental conditions that favor mold growth. More information for each drying system can be found in other Extension publications.

For bin-drying systems, the amount of air delivered by a fan decreases as grain depth increases. For this reason, **grain depth must be limited** to a level that allows adequate airflow for these systems to be successful. Systems providing less than two cubic feet of air per minute for each wet bushel (cfm/bu) can easily develop aflatoxin problems if overloaded (see Table 3).

In bin dryers that are not equipped with stirring equipment, the top layer is always the last to dry. Hence, it is an area likely to have temperature and moisture conditions favoring mold growth for extended periods. This is especially true during warm weather (above 60°F). Avoid loading full bin and layer drying systems with corn above the limits shown in Table 3. Otherwise, mold growth could develop in the top layer of grain.

Consider switching from full bin drying to layer drying or stir-drying when more drying capacity is required. This can be accomplished by adding a larger fan, heater, or stirring equipment. Fill rates can then be adjusted so that wet corn starts to dry before more grain is added to the bin.

The chance of a post-harvest aflatoxin problem is lower with high-temperature bin drying systems because the corn is normally dried within 14-20 hours and cooled within 48 hours after harvest. Grain may be dried in a stationary bed (usually 2½ to 4 ft deep) or in bins with stirring equipment (up to 6 ft deep). Grain temperature and moisture sensors can be installed in new or existing bin dryers to control unloading equipment or fan and heater operation. Dry grain can then be automatically transferred to a storage bin for cooling.

Table 3. Recommended operating conditions for corn drying systems.

Drying System	Maximum Harvest Moisture Content,%	Approximate Airflow cfm/bu
Bin Dryers		
No Heat/ *(Sept)*	16%	1-2
Low Temp. *(Nov)*	18%	
Layer Fill (with heat)		
(no stirring)	22%	2-5
(with stirring)	22%	2-5
Medium Temp.	28%	8-12
High Temp.	28%	15-60
Column Dryers (automatic batch/ continuous flow)	28%	75-150

Column dryers and high-temperature bin dryers (automatic batch and continuous flow units) provide the most capacity and flexibility for drying corn at high moisture levels. Drying times are usually between ½ and 2 hours. A potential trouble area with these systems is the wet holding bin where grain accumulates as it is delivered from the field. When high moisture corn stays in the wet bin for an extended period, mold growth can start and accelerate rapidly.

Aeration in the wet holding bin helps provide some temperature control but is not a substitute for timely drying. Hopper bottom bins are preferred to hold wet corn since they are self cleaning. It is a good idea to periodically check that these bins empty completely before more wet grain is added. If a flat bottom bin is used to hold wet corn, use a power sweep auger to unload the bin completely each day or form a "false" hopper bottom with dry corn to facilitate daily unloading of wet grain. Wet grain should not be left in an aerated holding bin more than 48 hours before drying.

Another potentially troublesome area with high temperature drying systems is cooling hot corn too slowly. Hot corn should be cooled within 48 hours after it is dried. The recommended minimum airflow rate for cooling hot corn (0.5 cfm/bu of hot corn) exceeds the minimum rate for aeration alone (0.1 cfm/bu). Table 4 gives estimates of the time required to cool grain based on the size of the fan. Run the fan continuously when cooling hot corn in a bin to remove condensed moisture that collects on the inside wall and roof of the bin.

Storage Considerations

Mold growth can flourish and produce aflatoxin and other mycotoxins within a matter of days in a storage bin

Table 4. Approximate Operating Time for Different Size Fans (by horsepower).

Fan capacity hp/1000 bu	Hours of fan operation	Operating mode when cooling hot corn	Operating mode when aerating
1	15 - 20	C*	I
3/4	20 - 25	C	I
1/2	30 - 40	C	I
1/4	60 - 80	NR	I
1/5	75 - 100	NR	C
1/10	150 - 200	NR	C

** I= intermittent fan operation when the air temperature is in the desired range and the humidity is less than 70%. C= continuous fan operation for the time shown. NR = not recommended.*

Table 5. Recommended Grain Temperatures for Storage in Western Kentucky.*

Month	Average air temp.	Target grain temp.
September	70°F	60 - 70° F
October	60°F	50 - 60° F
November	47°F	42 - 52° F
Dec - Feb	37°F	32 - 42° F

**See AEN-45 "Aeration, Inspection, and Sampling of Grain in Storage."*

if corn is not dried and cooled thoroughly. Controlling corn moisture and temperature is the most cost-effective method of preventing spoilage problems. Clean corn that is dried to 15 to 15.5% moisture should store well for up to 6 months if it is cooled quickly and held at the recommended temperatures (see table 5). Corn that will be held for 9 months should be dried to 14%. A 12-month storage period requires a 13% storage moisture to reduce the risks of mold development and aflatoxin production. Corn that has excessive fines (>5%) should be drier than these levels by 1/2% to control storage risks. See AEN-20 for a more complete discussion of safe storage conditions.

When transferring dry corn to storage bins open roof vents and run bin fans to help remove light trash and dust that can form pockets and block air flow during aeration. Avoid overfilling storage bins. Pull the center core of material out of each storage bin as soon as possible after filling to remove trash and fines. Grain from this area should be among the first to be fed or sold each year.

Keep the temperature of the corn within 5-10°F of the average monthly air temperature. This practice is essential to avoid moisture movement in the bin, which can lead to areas where molds can flourish. This is easily accomplished by running the fan about once a month when average air temperatures are within the desired range. See Table 5 for suggested temperature levels at different months in the storage period.

The amount of time required to operate aeration fans depends on the size of the fan and the number of bushels in the bin. See Table 4 for the approximate time required to force a temperature change completely through grain. These times will vary with the amount of trash and fine material in the grain.

Inspect stored corn every two to four weeks. *Please note that inspecting and sampling grain in bins pose risks to personal safety.* Be sure to obtain a copy of the Extension publication, "Aeration, Inspection and Sampling of Grain in Storage Bins, AEN-45".

Mold spores on broken kernel surfaces can infect and grow within 24 to 48 hours if appropriate conditions occur. Measure temperature and pull samples from below the grain surface at representative locations. Look at individual kernels for mold growth and insect activity, and measure the moisture content of the grain. Record your observations to form a baseline comparison for the next inspection.

If the grain temperature changes by five degrees or the moisture content by 1/2% or more, inspections should be more frequent. If conditions continue to escalate toward temperatures and moistures favorable for mold growth, run the aeration fan to cool the corn. If conditions cannot be controlled by cooling, remove the spoiled grain by transferring it to another bin and collecting more samples during unloading, or redry the grain to a safe level as quickly as possible. Be sure your moisture meter is reading within a half percentage point of that of your local elevator; it should give accurate readings over the full range of moisture levels (13 to 28 percent).

Further details on grain storage are provided in the UK Extension publications "Principles of Grain Storage, AEN-20", and "Aeration, Inspection and Sampling of Grain in Storage Bins, AEN-45".

Using Aflatoxin-Contaminated Grain

Cleaning

Aflatoxins are often present in highest concentration in broken and cracked kernels. Cleaning grain with a gravity table or rotary screen can reduce the aflatoxin concentration of a corn lot. This is a practical option that is sometimes successful in reducing aflatoxin contamination. For some producers, cleaning it offers a "first line of defense" for dealing with contamination. However, research shows that aflatoxin levels are not always reduced following cleaning, especially in highly contaminated lots. This is because aflatoxins can be present at high levels in kernels that appear sound and undamaged.

Cleaning has the best chance of significantly reducing aflatoxin content for lots with high levels of broken corn-foreign matter content (BCFM of 10% or more) and moderate levels of aflatoxins (below 100 ppb). Cleaning does offer the advantage of preventing the accumulation

of fines and trash in the center of the bin, which can improve air movement through the grain in storage. Screenings should **not be fed** to any livestock because of a potentially high concentration of aflatoxins or fumonisins (another class of mycotoxins sometimes found in corn grown in the Midwest and South).

Feeding

Feeding to appropriate livestock is probably the best use of most aflatoxin-contaminated corn. On-farm feeding, or sale to a livestock operation in-state or out-of-state, are all acceptable uses of the corn. While the seller may suffer a price discount, in many cases this represents the best available option. If the aflatoxin level exceeds 20 ppb and the corn is being marketed out-of-state, FDA requires that the bill of lading clearly indicate that the corn is destined for the appropriate subgroup of livestock indicated in Table 2. Before feeding contaminated corn to livestock, be sure to obtain one or more accurate estimates of the level of aflatoxins in the lot.

As mentioned, most livestock disease conditions caused by aflatoxins are related to liver damage and generally result in decreased appetite, decreased growth rate or performance (i.e., drop in milk or egg production), unthriftiness, jaundice and rough hair coats. In addition, because of lowered disease resistance, aflatoxin-exposed animals will often become more susceptible to bacterial, viral, and/or parasitic diseases.

There are no clear-cut safe levels for different animal species regarding resistance or tolerance to aflatoxins. The recommended level of aflatoxins in feed is 0 ppm. However, aflatoxin-contaminated feed can be tolerated by some animals, particularly mature ones. Obviously, the higher the level of contamination, the greater the risk in feeding to animals. Furthermore, continued proper storage is essential so that aflatoxin levels do not continue to increase in the grain or prepared feed.

Consider the following points when making a decision on using aflatoxin contaminated grain.

1. Adequately determine the aflatoxin concentration in the grain.
2. Determine the age and species of livestock to be fed:
   a. Young, fast growing animals are most adversely affected within a species.
   b. Breeding stock may not be affected but the developing fetuses are very susceptible to low levels of aflatoxins.
   c. Ducklings, turkeys, chickens, swine, other simple stomach animals, ruminants and sheep are affected in decreasing order.
3. Estimated value of the affected grain is reduced by the potential detrimental effects of aflatoxin contamination. Compare this to the cost of locating and feeding non-contaminated grain.
4. Consider your willingness to assume risks associated with feeding contaminated grain.

Table 6. Recommended Maximum Concentrations of Total Aflatoxins in a Complete Diet for Livestock.

SPECIES		Maximum Level (parts per billion, ppb)
SWINE	birth to 75 lbs	20
	75 lbs to market	100
	adult swine	50
POULTRY	layers	50
	broilers	20
	turkeys	20
	ducks	20
	breeders *(broilers, layers, turkeys & ducks)*	avoid feeding any level
BEEF	mature cattle	300
	weaned calves	100
	mature cattle *(lactating)*	20
DAIRY	all classes*	avoid feeding any level
SHEEP**	lambs	50
	adults	400
HORSE		10

**The maximum allowable level of aflatoxin fed to dairy cattle is 20 ppb. When aflatoxins are consumed by lactating cows, it appears in the milk within 24 hrs. Because aflatoxins also are of concern to human health, a maximum level of 0.5 ppb is permitted in bulk tank milk. Once affected feed is removed, aflatoxin levels in the milk will disappear in 48 to 72 hours. Since feeding any grain contaminated with aflatoxin presents a large economic risk in calves and sale of milk, a clean feed supply appears to be a logical recommendation.*

***Under most management systems sheep receive very little grain as a feed product. Lambs do receive more grain and are more sensitive than adults, who appear to be the least sensitive farm species to aflatoxins.*

The recommended **maximum** concentrations of aflatoxins in a complete diet are listed in Table 6, and can be used as a guideline for various species. Recognize that there may be other unidentified mycotoxins in corn invaded by *Aspergillus* or other fungi. Predicting the precise effects of utilizing feeds of known analytical composition is still difficult.

Fortunately for the livestock industry, recent research has shown that the toxicity of aflatoxins may be influenced by dietary supplements. The addition of non-nutritive binding agents, such as the zeolite clays (sodium bentonite, Volclay, American Calloid Co., Arlington Heights, IL), and aluminosilicates (like NovaSil, Englehard Chemicals, Cleveland, OH) have been shown to be effective protectants against aflatoxin toxicity. The basic mechanism for their action appears to involve aflatoxin chemisorption in the gastrointestinal tract of animals, resulting in a major reduction in aflatoxin bioavailability.

When added at a rate of 10 lbs/ton (0.5%), these binding agents prevented most of the reduction in performance that occurred when aflatoxin levels of 1000 ppb were fed to pigs and 7000 ppb were fed to layers and broiler chicks. Furthermore, these chemical compounds decreased the

level of aflatoxin M1 in the milk of lactating dairy cows.

Presently, these compounds are allowed by the FDA at a level up to 2% in complete diets for use as "anti-caking" agents. However, they have not been approved on aflatoxin binding claims. These compounds will not stop mold growth in the feed. The cost of adding binding agents is approximately $1 to 4/ton of complete feed. Because there are no practical methods of economically decontaminating large volumes of aflatoxin-contaminated grain, the use of the chemical feed additives which bind the mycotoxin provides an option for using contaminated corn.

Ethanol Production

Aflatoxins do not appear in distilled alcohol, even when the corn has relatively high levels of toxin. The toxins are not degraded during fermentation and distillation but simply are concentrated in the spent grain. Thus, ethanol plants can utilize aflatoxin-contaminated corn, although they may prefer not to, because of a desire to use the spent grain as livestock feed.

Blending

One method of reducing moderate levels of aflatoxin contamination is to blend contaminated grain with clean grain. For reasons explained below, blending is intended ONLY for on-farm use. If not done properly, blending poses the risk of contaminating clean corn with unacceptable levels of aflatoxins. Accurate sampling is essential if blending is to be successful. If contamination levels in one lot are much higher than measured, the entire blended lot may become unacceptable. To ensure uniform mixing, lots to be blended should be fed into a common auger at rates needed to obtain the desired blend.

Blending is not an approved practice by the U.S. Food and Drug Administration for interstate commerce, and FDA considers blended lots to be adulterated. Blending is a practice intended to reduce aflatoxin to acceptable levels in small lots only for on-farm use. In many cases, the best option for using aflatoxin-contaminated corn may be to segregate contaminated corn and feed it appropriately as described above, rather than blending.

If blending is the option of choice, it can be accomplished if one of the lots of grain is at a lower concentration level than the desired final mixture.

For example, suppose grain with 250 ppb was to be blended with grain that had no contamination to obtain a final product having 50 ppb. Using the above equation:

(250 - 50) ÷ (50 - 0) = 200 ÷ 50 = 4

Therefore, four units of the least contaminated grain (0 ppb) are required for each unit of the most contaminated grain (250 ppb) to obtain a final blend of 50 ppb.

If the least contaminated grain contained an aflatoxin concentration of 30 ppb, you would need ten units of the least contaminated grain (30 ppb) for each unit of the most contaminated grain (250 ppb) to obtain a final concentration of 50 ppb in the blended grain, as indicated in the calculation below.

(250 - 50) ÷ (50 - 30) = 200 ÷ 20 = 10

Obviously, one of the grains to be blended must be lower in concentration than the desired final concentration. The above examples illustrate the importance of obtaining an accurate measure of aflatoxin concentration. Slight differences can radically change the blend ratios. Also, the moisture of the final blend must be dry enough for safe storage (no higher than 15.5% during winter and 13% during summer).

Ammoniation

Detoxifying the grain with anhydrous ammonia is an alternative where the corn is to be used on the farm. Ammonia, applied as either a gas (anhydrous ammonia) or liquid (aqua-ammonia), reacts with the aflatoxin molecule to destroy its toxicity. Proper treatment can reduce aflatoxin concentrations by 95% or more. Swine and poultry may be reluctant to eat the treated grain if an ammonia smell is present, but otherwise no problems have been reported from feeding treated corn to livestock.

While potentially valuable in some instances, ammoniation poses several problems. Ammoniation is not an FDA-approved practice for corn in interstate commerce. Thus, treated corn must be used on-farm or sold for use within the Commonwealth. Concentrated anhydrous ammonia is hazardous to humans and livestock, explosive, and corrosive to equipment and storage bins. Ammoniation also discolors the grain, turning it a light caramel color which may be objectionable to buyers.

$$\text{Ratio of least contaminated grain to most contaminated grain} = \left[\left(\text{Aflatoxin concentration in the most contaminated grain, ppb}\right) - \left(\text{Aflatoxin concentration in blended grain, ppb}\right)\right] \div \left[\left(\text{Aflatoxin concentration in blended grain, ppb}\right) - \left(\text{Aflatoxin concentration in the least contaminated grain, ppb}\right)\right]$$

Ammoniation is a hazardous operation. It should be done only by trained operators who have the proper application and safety equipment. Applicators must be thoroughly knowledgeable in the handling of ammonia products. Casual attempts to ammoniate corn are likely to produce poor results and serious injuries.

Others

Roasting corn at 290-330° F can reduce in aflatoxin content ranging by 40% to 80%, with higher temperatures resulting in greater reductions. However, the temperatures required to reduce aflatoxin content are higher than those used in a normal corn roasting process. Some loss in feed value can be expected when using these temperatures for roasting.

Ensiling of contaminated high-moisture corn does not adequately degrade aflatoxins.

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