# 10 - Grain Storage and Aflatoxin in Corn

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## Introduction

Arkansas farmers and grain dealers are concerned with aflatoxin in corn. Aflatoxin is a major problem for corn producers and handlers in some years and only a minor problem in others. This chapter describes aflatoxin, methods of managing corn to reduce aflatoxin and remedial treatments for contaminated corn.

## What Is Aflatoxin?

Aflatoxin is a chemical produced by several *Aspergillus* fungi, primarily *Aspergillus flavus* and *Aspergillus parasiticus*, under certain conditions when they grow in ears or on grain. These fungi also cause ear rots, but their presence does not always mean aflatoxin contamination.

Aflatoxin is most commonly found in corn, peanuts, cottonseed and their processed products and only rarely is noted in wheat, oats, sorghum, rice and soybeans. Aflatoxin in the diet adversely affects the growth and development of cattle, poultry, swine, fish and other animals. Liver disease and certain cancers have been associated with diets containing aflatoxin in some animals. High levels of aflatoxin can be lethal in all farm animals, but young pigs, pregnant sows, calves and young poultry are more susceptible than mature animals.

The Food and Drug Administration has established “action levels,” measured in parts per billion (ppb), for aflatoxin in animal feeds or food. This makes animal feeds subject to regulatory action if aflatoxins are detected above the following levels:

- 300 ppb for corn intended for finishing (i.e., feedlot) beef cattle and for cottonseed meal intended for beef cattle, swine or poultry;
- 200 ppb for corn intended for finishing swine of 100 pounds or greater;
- 100 ppb for corn intended for breeding beef cattle, breeding swine or mature poultry;
- 20 ppb for corn intended for human food, immature animals (including immature poultry) and for dairy animals, or when its destination is not known;
- 20 ppb for animal feeds other than corn or cottonseed meal.

## How Corn Is Contaminated with *Aspergillus* sp.

*Aspergillus* overwinters primarily in plant debris and litter on the soil. Spores of *Aspergillus* spp. are airborne and fluctuate in number during the growing season. Spores tend to increase during tillage and harvest and may be further increased in dryland corn.

Infection of corn by *Aspergillus* spp. occurs through the silk. The fungus appears to grow from the ear tip toward the base by colonizing the silk first, then the glumes and the kernel surface. After the silks die, the growth of the fungus is rapid in hot weather.

Factors influencing infection of corn ears by *Aspergillus* spp. and aflatoxin contamination include stress-related situations and insect damage. Corn plants exposed to drought stress are more susceptible to infection and contamination by aflatoxin than unstressed plants. Although insect damage is not necessary for aflatoxin formation, the incidence of *Aspergillus* and levels of aflatoxin contamination can be higher in insect-damaged kernels.

## Prevention or Reduction of Aflatoxin in Corn

If conditions are favorable for the production of aflatoxin, it is much more difficult to prevent infection from *Aspergillus* spp. and subsequent aflatoxin production. Thus, a realistic goal is to minimize the preharvest infection with sound agronomic practices and minimize post-harvest fungal growth with careful handling and storage practices.

Since the fungus normally colonizes stressed, cracked or broken kernels, reducing in-field stress and kernel injury is recommended, including:

- Plant early to avoid drought stress and insect damage. Corn may be planted successfully when the morning soil temperature is 55˚F at a 2-inch depth for three consecutive days. This normally occurs in late March in south Arkansas and early April in north Arkansas. Sometimes frost may occur after these planting dates, but corn normally withstands frost with very little injury.

- Irrigate properly to avoid drought stress. Irrigation scheduling can prevent moisture stress and protect yield potential by allowing uniform kernel development. A computerized irrigation scheduling program and a manual checkbook program for scheduling irrigation are available at county Extension offices. If tensiometers are used to schedule irrigation, initiating irrigation at 50 centibars on silt loam and clay soils and 40 centibars on sandier soils is recommended.

- Plant Bt corn hybrids adapted to the south and with good husk cover to minimize insect and other stresses.

- Control late-season ear- and stalk-feeding insects as needed.

- Harvest unstressed portions of fields separately from portions of fields that suffered drought stress (e.g., in a field irrigated with a center pivot system, harvest inside the irrigated circle first and leave the nonirrigated corners for later). Mixing clean grain with moldy grain on the truck is not recommended. The best approach is to keep clean grain separate from grain that is suspected to be contaminated.

- Research indicates the best kernel quality usually results when corn is harvested within a range of moisture levels between 19 and 24 percent. The routine recommendation, based on discounts/drying costs and field losses, is that corn be harvested between 15 and 18 percent moisture. This is an economic decision based on a typical crop that has no increased risk for lodging, charcoal rot or aflatoxin contamination.

If high-moisture corn can be dried rapidly, at-risk fields should be harvested earlier, before they reach 18 percent moisture. This reduces kernel damage and the potential sites for aflatoxin contamination. High-moisture corn harvest also reduces field loss, but it increases drying costs. To reduce damage during combining:

- Use a rotary thresher, if available.

- Start with a thresher speed that is slow enough to leave a few kernels on the cob. Don't overload the thresher or the cleaning sieves.

- Replace worn grain augers. Grain augers damage kernels if their diameter is worn to the point that kernels slip past the flighting.

- Adjust the combine airflow and sieve settings to remove foreign material from the corn sample. Separating foreign material from grain eliminates a primary source of moisture and material that restricts air movement in the bin. Some broken kernel portions will blow over the sieves and onto the field. Proper thresher settings and post-harvest screen separators are practical ways to eliminate broken kernel portions. Start with the combine manufacturer's suggested settings and fine-tune the combine to obtain a clean sample.

Eliminating fines is economically done with a screen as grain is emptied from the truck hauling it in from the field. This rotating screen fastens to the grain auger and eliminates fine material. If these fines are contaminated with aflatoxin, they should be burned or buried. Contaminated fines should never be used for livestock feed. Clean combines, grain carts, trucks, conveyors and bins thoroughly after they have been used for corn.

## Grain Storage to Preserve Quality

Many aflatoxin problems arise during grain storage, which begins the moment the kernel enters the grain tank on the combine. At that moment, the quality of the grain is the best it will ever be. The first objective in preserving grain quality is to determine grain moisture level, amount of trash in the grain, amount of grain damage that has occurred and best utilization of facilities and manpower available.

Grain that is cracked or has a lot of foreign matter is susceptible to mold growth and is hard to dry because of decreased airflow. The kernel seed coat offers protection from invasion of a variety of pests including insects and molds. Grain should be handled carefully so as not to mechanically damage the seed coat. Also, stress cracking due to overheating or drying too rapidly should be avoided.

Air movement through grain helps avoid the natural heating process that occurs with any material containing high moisture. It is essential that grain not be held in the field for any period of time to avoid heat stress and fostering mold systems. If possible, move grain to the drying and storage area immediately after harvesting and begin to move air through it to start the drying process. Ideally, move grain to a drying operation in less than six hours from the time it is harvested. A 24 hour delay may cause problems, including high rates of *Aspergillus* growth and aflatoxin production.

Relative humidity, kernel moisture and temperature play a role in aflatoxin development on corn. Conditions favoring the growth of *A. flavus*, include:

| Factor | Optimum |
|---|---|
| Temperature | 80˚-100˚F |
| Relative Humidity | 85%-100% |
| Kernel Moisture | 18% and above |

These factors act in combination. If the relative humidity can be lowered with air movement and the grain moisture is reduced, the potential of mold problems decreases. Development of the fungus usually stops when the temperature is below 55°F and grain moisture is 12 percent or less, but it is greatly reduced at moisture levels of 15 percent or less.

## Store Grain at Low Moisture Content

The relationship between the moisture content of stored grain and the relative humidity of the air profoundly affects mold growth and grain spoilage. The moisture content of stored grain determines the relative humidity of the air in which it is stored. High moisture content causes high relative humidity in the air surrounding the grain in storage. Molds grow rapidly when the air has a high relative humidity and slowly at a low relative humidity. In fact, each mold has a specific relative humidity below which it will not grow. When grain is stored with low moisture content, air contained in the grain mass has low relative humidity and grain deterioration by mold growth is controlled. The best way to control mold growth is to store grain with low moisture content. The safe moisture storage level for corn in Arkansas is approximately 12 to 13 percent. Long-term storage should be 12 percent.

## Avoid Pockets of Damp Grain

For safe storage, all the grain must be below this safe storage moisture level. An isolated pocket of damp grain supports mold and/or insect growth which can spread upward and outward to drier grain. A load of damp grain placed in storage with dry grain limits the storage time of the entire lot to that of the wettest grain. Research has shown that even when damp and dry grain are carefully mixed and moisture is allowed to equalize, moisture differences of 2 percent between kernels may remain. When the grain is poorly mixed, much greater differences result.

Pockets of high moisture can be the result of adding a damp load to dry grain, even when mixed. A column of fine and heavy foreign material often accumulates under the filling spout creating a trouble spot. Light trash, especially green trash, usually accumulates near the walls of storage bins as it rides down the cone of grain during filling of the bin. Don't allow the incoming grain to cone inside the bin. Any leaks in the storage bin also cause pockets of high moisture grain.

## Avoid Moisture Migration

A frequent cause of pockets of higher moisture grain in storage is moisture migration. Grain in the mid-south region is usually warm when harvested and stored. Since grain is a good thermal insulator, it remains warm until cooled by aeration. During cold seasons, air near the bin wall cools, and convective currents are set up in the bin. Warm air in the center of the grain mass tends to rise and absorb moisture due to its greater moisture carrying capacity. As this air reaches the cool grain surface at the top and center of the grain column, it is cooled and gives up some of its moisture, which is absorbed by the grain. This moisture migration causes a pocket of higher moisture grain at the top center of the stored grain. During the winter, this process can cause a pocket of 18 to 20 percent moisture in a bin of grain that was originally uniformly 14 percent or lower. When the temperature rises in the spring, moist grain may germinate and storage mold will rapidly invade the grain.

Moisture migration can be prevented by aeration. Aeration during dry, cool days equalizes temperatures within stored grain and prevents convective currents.

## Do Not Rely on Grain Turning

Turning grain (moving it from one bin to another) is used by farmers in an attempt to prevent or stop heating and deterioration. Research has shown that turning does not make any important reduction in average temperature or average moisture content of a bin of grain. Also, turning scatters mold and insects throughout the bin. Only when moisture content is uneven will turning be effective in temporarily slowing heating and deterioration by mixing damp grain with dry grain in the bin. Grain turning should be considered a last resort to save a deteriorating lot of grain. Aeration is more effective for maintaining grain quality during storage, and excessive handling increases kernel damage.

## Control Insects and Rodents

Insects which invade stored grains are also sensitive to temperature. Their growth and reproduction are greatly reduced at temperatures below 70°F and cease at 50°F. Good housekeeping and spraying operations are generally sufficient for control. Rodents are controlled by storing grains in rodent-proof bins. Both insect and rodent control are enhanced by keeping grain facilities clean of old grain, debris and vegetation. For details see fact sheets:

- Gardisser, D. R., 1989, *Chemical Applicators for Spraying Liquid Materials on Grain*, FSA-1006, University of Arkansas Cooperative Extension Service.

- Gardisser, D. R., 1989, *Calibration of Stored Grain Chemical Applicators*, FSA-1004, University of Arkansas Cooperative Extension Service.

## Check Moisture Content During Storage

Anyone who stores grain should own or have access to a grain moisture tester and know how to use it properly. Calibrate the moisture tester before each harvest season. It can be shipped to the manufacturer for calibration or checked against another tester known to be accurate. When buying a moisture tester, check with the manufacturer for the best method of calibration.

When making moisture tests to determine the condition of grain in storage, don't enter a grain bin without a safety harness and tether manned by at least one adult outside the bin whose sole responsibility is aiding the entrant. Turn off all unloading equipment and lock out electrical controls so no one can unwittingly engage the power while you are sampling the areas which are likely to have the highest moisture content. Collect a sample near the top center of the grain. Use a grain probe to collect a representative sample from the area beneath the fill-in spout where fine material tends to collect. If the grain contained light trash that collected near the bin walls, sample these areas as well. Remember, the wettest sample determines how well the grain will keep.

To determine the average moisture content of the grain, take three samples – one on top, one near the center and one near the bottom. Openings in the bin wall or a grain sampling probe are required.

Keep samples that will not be tested immediately in airtight containers with as little air space as possible left in the container. Metal cans or glass jars with airtight lids or tight plastic bags are suitable for holding samples.

Don't test cold grain in a warm room. A thin film of moisture may condense on the kernels and cause erroneous readings. Either let the grain warm up in a closed container or operate the tester in an unheated room. Some electric moisture testers require temperature corrections. In this case, accurate temperature measurement is a must.

## Check for Hot Spots During Storage

A "hot spot" in stored grain indicates activity or mold growth. It may be due to a pocket of high moisture grain or a collection of fine material restricting aeration airflow. Temperature measurements in stored grain can detect "hot spots" before they do serious damage.

Temperature readings can be made using a probe consisting of a sensing element, probe handle and meter. Sections can be coupled together to check grain at depths up to 18 feet or more. If a "hot spot" is detected, make several checks to determine its size. Cool any "hot spots" as soon as possible by aeration. If the hot spot is due to fine material that is restricting airflow, break up the "hot spot" by removing grain from the bottom of the bin and returning it to the top.

## Drying

Four commonly used drying systems include natural air or low temperature, layer, batch-in-bin and high temperature pass dryers. Drying air is forced up through the grain mass in each of these systems. Each system has advantages. Bin drying is most practical for small volume producers. High temperature drying is fastest but requires the greatest amount of investment and energy input.

The top or outer layer is always the last to dry. The drying layer moves up from the bottom so the top layer of grain is held longer at conditions which are ideal for aflatoxin production. Dry the top layer to below 18 percent moisture quickly. Following are some guidelines:

| Initial Grain Moisture | Drying System |
|---|---|
| Above 20% | High temperature batch, continuous flow or batch-in-bin. |
| Below 20% | Layer drying in bins with supplemental heat (if needed) to reduce the relative humidity of the incoming air to 50% to 55% or high temperature drying. |
| Below 16% | Natural air drying when climatic conditions permit or drying with supplemental heat in bins during the high relative humidity days. Aerate as needed to control temperature. |

## Equipment

- Use a properly sized fan to provide an adequate amount of airflow through the grain. As the grain depth in a bin increases, a larger fan is needed because of the additional power needed to move air through a column of grain. Also, higher moisture levels require more air to obtain a satisfactory drying level. The following table is a guide to determine how much air movement is necessary for safe drying at various moisture levels.

| Moisture Level (%) | Minimum Airflow (CFM per Bushel) |
|---|---|
| 11 to 13 | 0.5 |
| 13 to 15 | 1 |
| 15 to 18 | 2 |
| 18 to 20 | 3 |
| 20 to 22 | 4 |
| 22 and above | 6 |

- Equip all drying fans with heaters. Heaters are necessary for 24-hour drying. During the nighttime hours, relative humidity increases and heat is necessary to continue drying. Layer drying is slow even with 24-hour operations. Checking the relative humidity of the air manually or using thermostat and humidistat controllers for the heaters is necessary. (Controllers should be checked manually to ensure they are working correctly.)

- If you know the air temperature and relative humidity, you can determine the equilibrium moisture level of the air. If the moisture level of the grain is higher than the air equilibrium moisture level, drying occurs when air is moved through the grain. The speed of drying is determined by the difference between these moisture levels and the amount of air moved. The dryer the air and the larger the volume of air moved through the grain, the faster the drying process occurs.

- Bins should have adequate air exhaust in the roof to avoid choking the fan. Any bin larger than 2,500 bushels needs extra roof vents in addition to the standard manhole (inspection door) and the center fill hole. A good rule of thumb for determining the number of square feet of roof vent area needed is to multiply the fan horsepower by 1.25. (Example: 20 horsepower fan multiplied by 1.25 = 25 $ft^2$ of roof vent area needed.)

- Level each layer of grain as it is placed in the bin. Use a grain distributor to help level grain and distribute any fines evenly across the surface. Do not let the fines form a core in the center of the bin.

- If the equilibrium moisture level of the drying air is below that of the grain moisture, the drying process should continue until the top layer is dried to 13 percent. Air should be conditioned as necessary during high humidity swings to ensure that re-wetting of the bottom layer does not occur.

- More details on grain drying may be obtained in Extension publication MP-213, *Grain Drying – Using Psychometric and Moisture Equilibrium Charts as Guides*.

## Storage Tips

- If grain is stored with uniform moisture contents (maintained below 13 percent for corn), the grain will store safely without spoilage.

- When grain is stored with moisture contents above this safe level, reduce the grain temperature to inhibit mold development.

- For every combination of grain temperature and moisture content above safe levels, there is an allowable storage time before serious mold growth develops. Lower temperatures and lower moisture contents allow longer safe storage times.

- Moisture migration is caused by temperature differentials in stored grain and is prevented by aeration.

- Grains germinate when they are moist and warm enough. They heat when invaded by insects or storage molds.

- Be sure all old corn and trash are cleaned out of the storage bin before any new corn is added.

- Clean bins and the plenum area, including below the floor, and maintain the burners. Monitor the drying process to avoid fire in a corn bin.

- Immediately after drying is completed, cool the grain to outside air temperature.

- Treat corn while it is being placed into storage to control insect infestations.

- Operate the fan whenever the outside air is below 65 percent relative humidity and 10˚F cooler than the corn until the corn reaches 50˚F.

- Operate fans for aeration at least 4 hours every 2 weeks after the corn is cooled to 50˚F.

- Consider fumigation if insect problems develop in storage.

- Inspect corn frequently for mold, insects, hot spots or other signs of spoilage. The best insurance for stored grain is frequent inspection!

## Detection of Aflatoxin

Most farms in Arkansas do not have high levels of aflatoxin in corn, but occasionally grain has enough aflatoxin to cause problems in marketing and feeding. Farmers, elevator managers and feed manufacturers need to be aware of proper detection and identification of contaminated corn. Rapid detection of contaminated corn is important because aflatoxin normally survives processing and may be concentrated in products or processed fractions.

Many elevators in Arkansas use a high intensity ultraviolet light (UV) to detect a byproduct of *Aspergillus* growth in grain or feed. Infected corn emits a bright blue-green-yellow fluorescence when exposed to UV light. However, the fluorescence only indicates the presence of fungal activity and does not prove the presence of aflatoxin. Many elevators use a UV black light to screen grain samples.

Since the black light can result in false positives for aflatoxin, the grain industry now generally use ELISA test kits to directly detect aflatoxin in grain. These test kits are based on an antibody specific for aflatoxin. While these test kits are much more accurate in trained hands than the black light, they are only as representative as the sample collected from the truck. Since aflatoxin-contaminated grain is not randomly distributed in a truck load and since even a single contaminated kernel in a sample can cause the sample to exceed regulated levels of aflatoxin, these tests still result in inaccurate readings for the load, albeit the reading for the sample is probably accurate.

A new state law in Arkansas requires the Arkansas State Plant Board to investigate claims of aflatoxin contamination in commercial grain, so any grower receiving a positive result should contact the Plant Board for help.

## What Can Be Done with Contaminated Grain?

Occasionally, corn may be contaminated with aflatoxin at levels which disqualify it from normal marketing channels. When loads of grain are rejected for high aflatoxin, farmers and other users have some remedial treatments or options for their grain including:

- Blending aflatoxin-contaminated corn with aflatoxin-free corn is not legal.

- Grain preservatives such as propionic acid, isobutyric acid and other organic acids prevents the growth of *Aspergillus* sp. if properly applied to grain as it is augered into bins. However, these acids will not lower levels of aflatoxin in grain that is contaminated prior to treatment. Furthermore, these materials are very corrosive and should not be used in metal storage bins unless the metal is protected. If grain treatments are used, follow manufacturer's recommendations carefully.

- Fumigating corn with anhydrous ammonia is an effective means of detoxifying corn that could not otherwise be fed to livestock. However, the process is time-consuming and hazardous to those ammoniating grain. The FDA has not yet approved ammoniation as a process to salvage aflatoxin contaminated corn. Anytime anhydrous ammonia is used, all plumbing should meet O.S.H.A. standards and eye protection should be used.

- An activated clay, hydrated sodium calcium aluminosilicate (HSCAS), may be added to aflatoxin-contaminated feed to reduce the toxic effects of aflatoxin in swine, poultry and cattle. Some commercial products containing HSCAS are registered as anti-caking materials and may be added at labeled rates (0.5 to 2 percent of finished feed) to animal feed. These products appear to be the most cost effective method of using contaminated grain for animal feed.

## Summary

Aflatoxin can reduce the quality and marketability of corn. Contamination can originate in the field and increase dramatically during grain storage. Proper management of the crop, careful handling and proper storage of the grain are critical in preventing aflatoxin. Once contaminated, affected corn is very difficult to deal with.