FSA1100

Corn Drying, Storage and Aflatoxin Levels

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What is Aflatoxin?

Aflatoxin is a chemical produced by several *Aspergillus* fungi, primarily *Aspergillus flavus* and *Aspergillus parasiticus* (Trail et al., 1995). These fungi can colonize corn ears when damaged by insects or when under significant drought conditions. As a result, they cause Aspergillus ear rot, a disease that can reduce grain quality and storage longevity (Pearson et al., 2001). Most of the time, damage to the ear by Aspergillus ear rot is minor. Of greater concern, however, is the ability of these fungi to produce aflatoxin.

Aflatoxin is most commonly found in corn, peanuts, cottonseed and processed products. It is rarely noted in wheat, oats, sorghum, rice or soybeans. Aflatoxin in the diet adversely affects the growth and development of cattle, poultry, swine, fish and other animals. In addition, liver disease and certain cancers have been associated with diets containing aflatoxin (IARC, 1993; and Reddy et al., 2005). High aflatoxin levels can be lethal in farm animals, especially young pigs, pregnant sows, calves and young poultry.

In some years, aflatoxin may be considered a significant problem for corn producers and handlers in the southern United States, especially in non-irrigated corn. In other years it is only a minor problem (Abbas et al., 1999).

The goals of this fact sheet are to explore the definition of aflatoxin, to list the corn management methods to reduce aflatoxin and to identify remedial treatments for contaminated corn.

What are the Food and Drug Administration Action Levels?

The U.S. Food and Drug Administration has established “action levels” measured in parts per billion (ppb) for aflatoxin in animal feeds and food (see Table 1). This makes animal feeds subject to regulatory action if aflatoxins are detected above the following levels:

Table 1. The concentration of aflatoxin in animal feed and food (FDA, 2019).

Aflatoxin Concentration	Utilization as animal feed or food
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 dairy animals, or when their destination is unknown.
20 ppb	For animal feeds other than corn or cottonseed meal.

How is Corn Contaminated with *Aspergillus* spp.?

Aspergillus survives primarily in plant debris and on organic material in 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 increase further in hot, dry weather or dryland corn (Anderson et al., 2004).

Infection of corn by *Aspergillus* spp. occurs through the silk. The fungus grows from the ear tip toward the base by colonizing the silk first, then the glumes and the kernel surface. Corn plants exposed to drought stress are therefore more susceptible to infection and contamination by aflatoxin than unstressed plants. It should also be mentioned that levels of aflatoxin contamination can be higher in insect-damaged kernels (Dolezal et al., 2014).

Prevention or Reduction of Aflatoxin in Corn

A realistic goal is to minimize the preharvest contamination of corn with aflatoxin. This can be achieved using sound agronomic practices and minimizing post-harvest fungal growth through careful handling and storage practices (Summer and Lee, 2017).

Since the fungi usually colonize stressed, cracked or broken kernels, we recommend reducing in-field stress and kernel injury. Strategies include:

- 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 typically occurs in late March in south Arkansas and early April in north Arkansas. Sometimes frost may occur after these planting dates, but corn typically withstands it with minimal 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 are recommended.
- Plant Bt corn hybrids adapted to the South and with good husk cover to minimize insect feeding.
- Control ear- and stalk-feeding insects as needed.
- Harvest unstressed portions of fields separately from portions of fields that suffered drought stress. For example, in a field irrigated with a center pivot system, harvest inside the irrigated circle first and leave the non-irrigated corners later. Mixing clean grain with the moldy grain on the truck is not recommended. Instead, the best approach is to keep clean grain separate from grain suspected to be contaminated.
- Research indicates the best kernel quality usually results when corn is harvested within a range of 19-24 percent moisture levels. Based on discounts, drying costs and field losses, the routine recommendation is to harvest corn between 15-18 percent moisture. This is an economic decision based on a typical crop with no increased risk for lodging or aflatoxin contamination (Bern et al., 2002).

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

- Start with a thresher speed that is slow enough to leave a few kernels on the cob. Do not 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. However, 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 being used for corn.

Grain Storage to Preserve Quality

Many aflatoxin problems arise during grain storage, which begins when the kernel enters the grain tank on the combine. At that moment, the quality of the grain is at its best. However, the quality of the grain may start to reduce if it is stored in an improper environment. For instance, Table 2 shows the conditions favoring the growth of *A. flavus*, which need to be avoided. Therefore, the first objective in preserving grain quality is determining grain moisture level. Additionally, it is essential to determine the amount of foreign material in the grain and damaged grain (Loewer et al., 1994).

Grain that is cracked or has much foreign material is susceptible to mold growth. The kernel seed coat offers protection from the invasion of various pests, including insects and molds. Grain should be handled carefully so as not to damage the seed coat mechanically. Also, stress cracking due to overheating or drying too rapidly should be avoided.

Air movement through grain helps avoid the heating process that occurs naturally with any material containing high moisture. Grain must not be left in the field for a longer period to avoid heat stress and excessive mold growth. If possible, move the grain to the drying and storage area immediately after harvesting and move air through it to start the drying process. Ideally, move grain to a drying operation within six hours of harvest. A 24-hour delay may cause problems including high rates of *Aspergillus* growth and aflatoxin production. Relative humidity, kernel moisture and temperature also influence aflatoxin development in corn.

Table 2. Conditions favoring the growth of A. flavus (Summer and Lee, 2017).

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

The above mentioned factors act in combination. For example, suppose the relative humidity can be lowered with air movement and reduced grain moisture. In that case, the potential for mold decreases. The growth and reproduction of the fungi usually stop when the temperature is below 55°F, and grain moisture is 12 percent or less. However, it is significantly 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. High moisture content causes high relative humidity in the air surrounding the grain in storage. Molds proliferate when the air has high relative humidity. Each mold has a specific temperature and relative humidity below which it will not grow. When grain is stored under certain low moisture content, the air in the grain mass may have low relative humidity, and grain will not deteriorate by mold growth. The best way to control mold growth is to reduce grain moisture content before storage. The safe moisture storage level for corn in Arkansas is approximately 12-13 percent. For long-term storage, corn should be stored at 12 percent (Bern et al., 2002).

Avoid Pockets of Damp Grain

For safe storage, all grain must be below the safe storage moisture level of 12 percent. An isolated pocket of damp grain supports mold and insect growth, spreading 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 even when the damp and dry grain is carefully mixed. Although moisture can equalize, moisture differences of 2 percent between kernels may remain when the grain is poorly mixed.

Pockets of high moisture can result from adding a damp load to dry grain, even when mixed. A column of delicate and heavy foreign material often accumulates under the filling spout, creating a trouble spot. Light dirt, especially green dirt (containing leaves or stems), usually accumulates near the walls of storage bins as it rides down the cone of grain when filling the bin, so don't allow the incoming grain to form a cone inside the bin. Any leaks in the storage bin also cause pockets of high moisture grain (Sadaka et al., 2017).

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 an excellent 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 more significant 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 absorbed by the grain. This moisture migration causes a pocket of higher moisture grain at the top center of the stored grain. This process can cause a pocket of 18-20 percent moisture in a bin of grain that was uniformly 14 percent or lower during the winter. When the temperature rises in the spring, moist grain may germinate, and storage mold will rapidly invade the grain. Aeration can prevent moisture migration. During dry, cool days, aeration equalizes temperatures within the stored grain and prevents convective currents (Loewer et al., 1994).

Do Not Rely on Grain Turning

Farmers sometimes move grain from one bin to another to prevent heating and grain deterioration.

Research has shown that turning does not significantly reduce a grain bin's average temperature or moisture content. The turning may also spread mold and insects throughout the bin. When the moisture content is uneven in the bin, however, grain turning will be temporarily effective. Grain turning will slow heating and deterioration by mixing damp grain with dry once in the bin. Grain turning should be considered a last resort to save a deteriorating lot of grain. Aeration is more effective in maintaining grain quality during storage, and excessive handling increases kernel damage (Loewer et al., 1994).

Control Insects and Rodents

Insects that invade stored grains are also sensitive to temperature. Their growth and reproduction are significantly reduced at temperatures below 70°F, and cease at 50°F. Good housekeeping and spraying operations are generally sufficient for control. Storing grains in rodent-proof bins will control rodents. In addition, keeping grain facilities clean of old grain, debris, and vegetation will enhance both insect and rodent control.

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. First, calibrate the moisture tester before each harvest season. It can then 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 calibration method (Sadaka and Rosentrater, 2019).

Do not enter a grain bin without a safety harness and tether manned by at least one adult outside the bin. The helper's responsibility is aiding the entrant during sampling grain for moisture content.

- Turn off all unloading equipment and electrical lockout controls so no one can accidentally engage the power while sampling the areas likely to have the highest moisture content. First, collect a sample near the top center of the grain. Next, use a grain probe to collect a representative sample from the area beneath the fill-in spout where fine material is collected; the grain-containing foreign material will be collected near the bin walls. Remember, the wettest sample determines how well the grain will be kept.
- 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.
- Do not 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 severe damage. Temperature readings can be done using a probe consisting of a sensing element, probe handle and meter. Sections can be coupled together to check grain at depths of 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 restricting airflow, break it up 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. Depending on the grain initial moisture content, try to use the corresponding drying system as shown in Table 3. 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 the fastest but requires the most significant 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 has ideal conditions for aflatoxin production. Dry the top layer to below 18 percent moisture quickly. General guidelines can be found in Table 3.

Equipment

- Use an appropriately sized fan to provide an adequate amount of airflow through the grain. As the grain depth in a bin increase, a powerful fan is needed to move air through a column of grain. Table 4 shows grain depth and airflow rate effects on corn's static pressure (inches of water). Also, higher moisture levels require more air to obtain a satisfactory

Table 3. Grain initial moisture content and the recommended drying system.

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) reduces 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.

drying level. The following table (Table 5) guides how much air movement is necessary for safe drying at various moisture levels.

- Equip all drying fans with heaters if possible. Heaters can allow for 24-hour drying if necessary. During the nighttime hours, relative humidity increases and heat is necessary to continue drying. Checking the relative humidity of the air manually or using thermostats 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 (https://www.uaex.uada.edu/publications/pdf/FSA-1074.pdf). 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 drying speed is determined by the difference between these moisture levels and the amount of air moved. Therefore, the dryer and the larger the air volume 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 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.
- Suppose the equilibrium moisture level of the drying air is below that of the grain moisture. In that case, the drying process should continue until the top layer is dried to 13 percent. Air should be conditioned as necessary

Table 4. Effects of grain depth and airflow rate on the static pressure (inches of water) for corn.

Grain Depth (ft)	Airflow Rate (cfm/bushel)*					
	0.25	0.5	0.75	1.0	2.0	3.0
2	0.52	0.51	0.51	0.52	0.54	0.56
4	0.54	0.53	0.55	0.58	0.68	0.80
6	0.57	0.58	0.63	0.69	0.95	1.29
8	0.61	0.65	0.75	0.86	1.40	2.10
10	0.66	0.75	0.91	1.09	2.04	3.28
12	0.73	0.87	1.12	1.41	2.90	4.90
14	0.80	1.03	1.39	1.81	4.02	7.00
16	0.89	1.21	1.71	2.30	5.41	9.63
18	1.00	1.43	2.10	2.88	7.10	12.86
20	1.11	1.69	2.55	3.58	9.11	16.72
22	1.24	1.98	3.08	4.38	11.47	
24	1.39	2.32	3.68	5.31	14.20	
26	1.55	2.69	4.36	6.35	17.32	
28	1.73	3.11	5.12	7.53		
30	1.92	3.58	5.97	8.85		

Table 5. Relationship between corn moisture level and fan minimum airflow rate.

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

during high humidity swings to ensure that re-wetting of the bottom layer does not occur.

- Refer to the Extension publication: Grain Drying Tools: Equilibrium Moisture Content Tables and Psychrometric Charts (https://www.uaex.uada.edu/publications/pdf/FSA-1074.pdf) for more information about grain drying.
- An airflow rate higher than the minimum rate shown in Table 5 should be used.

Storage Tips

- If the grain is stored with uniform moisture contents (maintained below 13 percent for corn), the grain will be stored safely without spoilage.
- When grain is stored with moisture contents above the safe level, reduce the grain temperature to inhibit mold development.
- There is an allowable storage time for every combination of grain temperature and moisture content above safe levels 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.
- Be sure all old corn and trash are cleaned out of the storage bin before adding new corn.
- Clean bins and the plenum area, including below the floor, and ensure that the burners are working properly. Always monitor the drying process to avoid fire in a corn bin.
- Immediately after drying is completed, cool the grain to the outside air temperature.
- Treat corn while it is being placed into storage to control insect infestations. Cylinerized phosphine, Sulfuryl fluoride are examples of the fumigant.
- 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 four hours every two weeks after the corn is cooled to 50˚F.
- Consider fumigation if insect problems develop in storage. Aluminum phosphide, Magnesium phosphide, and Methyl bromide are examples of the insecticides fumigant (https://www.uaex.uada.edu/farm-ranch/pest-management/docs/training-manuals/AG1161.pdf).
- Inspect corn frequently for mold, insects, hot spots, or other signs of spoilage. The best insurance for stored grain is a frequent inspection. Stored corn with a temperature above 55-60°F should be inspected every week and every two weeks when below 55°F.

Detection of Aflatoxin

Most farms in Arkansas do not have high levels of aflatoxin in corn. Occasionally, however, grain has enough aflatoxin to cause problems in marketing and feeding. Therefore, farmers, elevator managers and feed manufacturers need to be aware of the proper detection methods and identification of contaminated corn. Rapid detection of contaminated corn is important because aflatoxin typically survives processing and may be concentrated in products or processed fractions (King et al., 1979; Frisvad et al., 1992; Abbas et al., 2004).

Many elevators in Arkansas use 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 fungal activity and does not prove the presence of aflatoxin. Therefore, many elevators use UV black light to screen grain samples for the presence of *Aspergillus*.

The grain industry now generally uses ELISA test kits to detect aflatoxin in grain directly. The black light can result in false positives for aflatoxin. These test kits are based on an antibody specific to aflatoxin. While these test kits are much more accurate in trained hands than the black light, they are the only representative of the sample collected from the truck.

Aflatoxin-contaminated grain is not randomly distributed in a truckload. Even a single contaminated kernel in a sample can cause the sample to exceed regulated aflatoxin levels.

Any Arkansas grower receiving a positive result for aflatoxin should contact the Arkansas State Plant Board for help. Arkansas state law requires the plant board to investigate claims of aflatoxin contamination in commercial grain.

What can be done with Contaminated Grain?

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

- Grain preservatives such as propionic acid, isobutyric acid and other organic acids prevent the growth of *Aspergillus* spp. However, these acids will not lower levels of aflatoxin in grain that is contaminated before treatment. Furthermore, these materials are corrosive and should not be used in metal storage bins unless the metal is coated. If grain treatments are used, follow the manufacturer's recommendations carefully.

- Fumigating corn with anhydrous ammonia effectively detoxifies corn. However, the process is time-consuming and hazardous to those ammoniating grains. Texas, North Carolina, Georgia and Alabama have approved the ammoniation procedure for aflatoxin-contaminated corn. It should be mentioned that at any time anhydrous ammonia is used, all plumbing should meet OSHA standards and eye protection should be used.
- An activated clay, hydrated sodium calcium aluminosilicate (HSCAS), may be added to the aflatoxin-contaminated feed. This may reduce the toxic effects of aflatoxin in swine, poultry and cattle. In addition, 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. Therefore, proper crop management, careful handling and proper grain storage are critical in preventing aflatoxin. Once contaminated, infected corn is tough to deal with.

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Additional Resources

Aflatoxin fact sheet: https://servitechlabs.com/Portals/0/6_05_011%20Aflatoxin%20fact%20sheet.pdf.

Reducing Losses from Aflatoxin-Contaminated Corn: http://bell.agrilife.org/files/2011/09/aflatoxin-fact-sheet.pdf

Aflatoxins pose a serious health risk to humans and livestock: https://www.who.int/foodsafety/FSDigest_Aflatoxins_EN.pdf.

Aflatoxins in Corn: https://extension.missouri.edu/media/wysiwyg/Extensiondata/Pub/pdf/agguides/crops/g04155.pdf.

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