

Treating Aflatoxin-Contaminated Corn with Ammonia

*Originally prepared by
Cecil Hammond, Retired Extension Engineer*

*Reviewed by
Paul Sumner, Extension Engineer*

Electrocution from Grain Augers

Modern grain handling methods used by Georgia farmers make use of augers that are 40 to 60 feet long for placing grain into metal bins. Tragic accidents can occur when these long augers are moved from one bin to another without lowering the upper end which touches an overhead power line. Characteristically, two people will be holding the auger while moving it and both will be electrocuted. Consider installing underground electrical service if feasible or work with your local utility to move electrical wires that are dangerously close to metal grain bins.



Grain augers should be kept away from power lines.

Introduction

Corn containing more than 20 parts per billion aflatoxin cannot be legally shipped interstate. Markets for corn containing mold, whether it contains aflatoxin or not, are somewhat limited and prices depressed. The question is, what can the farmer do with aflatoxin contaminated corn? This publication explains how some simplified methods can be used for on-the-farm treatment of aflatoxin contaminated corn.

The logical first step in dealing with contaminated grain is to test and determine level of aflatoxin to see if it can be fed to livestock at an acceptable risk. Some farmers dilute aflatoxin corn with uncontaminated grain to make the ration less harmful to livestock. Others may clean the fines from the contaminated grain with some improvement in quality.

Anhydrous ammonia (gas) or aqua-ammonia (liquid) reacts with the aflatoxin molecule. It breaks the double oxygen bond and chemically alters and destroys aflatoxin. Since ammonia is only 0.6 as dense as air and is highly volatile, the grain to be treated must be sealed in an air-tight container (sealed in plastic) to prevent the ammonia from escaping into the atmosphere.

The FDA has not approved ammonia treated grain for legal interstate shipment. This does not prevent treatment and use of the contaminated grain on the farm. FDA has, however, approved the ammonia treatment of cottonseed meal as a feed additive. Some questions still exist as to the possible side effects of ammoniation, although no problems have yet emerged in feeding trials. It should be noted that ammoniated corn is darker in color due to the corn sugar being caramelized.

Safety

Be careful when handling ammonia. All provisions of the OSHA Regulations (29CFR 1910.111) must be followed when handling anhydrous ammonia. Only approved tanks, valves, lines, etc., can be used. Adequate water should be close at hand for flushing eyes or skin if an accident occurs. A small squeeze bottle filled with water and carried in a pocket ready for rapid flushing of the eyes in an emergency is highly desirable. Goggles, gloves, and a long-sleeved shirt should be worn for protection. Avoid breathing ammonia vapors and never allow a spark or flame near the ammonia. Also, ammonia is corrosive to metal (copper and brass fittings cannot be used) and reacts with galvanized metal, making ammonia very corrosive to grain bins.

Ammonia cannot be forced into a grain filled bin with a drying or aerating fan to successfully detoxify aflatoxin contaminated corn. Not only is the practice dangerous and destructive, the ammonia rapidly escapes and has little benefit. No spark, flame, or electrical equipment should be allowed near or exposed to ammonia.

Treatment Methods

Ammonia has a strong affinity for moisture and will readily combine with the moisture in grain at warmer temperatures. For this reason, more effective treatment can be expected for grains above 13 percent moisture and above 60°F. Grain below 13 percent moisture and at cooler temperatures can be detoxified with ammonia, but it will require a longer period of exposure to ammonia. Corn treated when above 17 percent moisture will “stick together” and stand on a vertical surface when the ammonia caramelizes the sugar in the corn. Once it’s broken apart with an end loader or similar handling devices, the corn will flow freely. Corn up to 15 or 16 percent moisture normally can be treated without sticking together.

Corn kernels exposed to ammonia immediately turn dark and increase about 10°F in temperature. Ammonia for grain treatment can be gaseous (NH₃) or liquid (aqua-ammonia, NH₄OH). Aqua ammonia is 26 to 29 percent ammonia at standard atmospheric pressure and temperature. Use 2.6 to 2.7 pounds of aqua-ammonia per bushel of corn for the 1.5 percent treatment rate. Adding this much moisture may require drying for storage after treatment.

Aqua-ammonia can be pumped through nozzles mounted in an auger housing if the nozzle is properly calibrated and the nozzles properly elevated above the auger housing to allow dispersion into the flowing grain. No recirculation of the ammonia gases is required when corn is treated using aqua-ammonia

sprayed into an auger for mixing, but the corn must be sealed (airtight) until treatment is complete (about a week under favorable conditions) to prevent the ammonia from escaping.

Gaseous ammonia can be taken from the top of an anhydrous ammonia tank with some inconvenience from freezing. If freezing occurs, close the valve and add more ammonia later. A “cold flow converter” can be used to prevent freezing of the ammonia. The ammonia container can be weighted or the level indicator gauge can be used on small tanks with sufficient accuracy to determine the amount of ammonia added.

Table 1. Thermodynamic Properties of Anhydrous Ammonia (NH₃)

Pressure (psi)	Temperature (°F)	Wt./Gal. (lbs)	Heat of Vaporization (BTU/lb.)
0	-28	5.7	589
10	-8	5.6	575
20	5	5.5	565
40	26	5.4	548
60	40	5.3	536
80	53	5.2	524
100	64	5.1	514
125	74	5.0	504
150	84	5.5	495
200	101	4.9	476

The freezing of the ammonia tank, lines, and valves can usually be prevented by using an ammonia tank containing two to three times the quantity of ammonia needed. This allows more tank surface to absorb heat from surroundings to provide heat for vaporization of the ammonia in the tank.

The temperature-versus-pressure relationship and the heat required for vaporization of ammonia is shown in Table 1. As the ammonia vapor is taken from the tank, the pressure and temperature of the liquid will decrease as the liquid ammonia boils in the tank to replace the vapor removed. To get an accurate measure of the ammonia used, the tank should be weighed. An estimate of the ammonia used can be made from the ammonia level indicator.

If aqua-ammonia is sprayed at the proper rate into an auger moving the contaminated corn, the ammonia is distributed throughout the corn mass and no recirculation of ammonia vapors is required. The corn must be sealed in an airtight envelope. The application of aqua-ammonia will add about two percent moisture to the corn for every percent of actual ammonia injected. This may eliminate the need for rewetting dry corn.

Rate of Ammonia Application

The rate of ammonia injected can vary from 0.5 to 1.5 percent of the corn dry weight (48 lbs./bu.). The lower rate would be recommended for corn over 15 percent moisture at grain temperatures over 80°F and with aflatoxin levels below 200 parts per billion.

The 1.5 percent rate would be recommended for lower temperatures and moisture levels and/or higher aflatoxin levels. Levels between 0.5 and 1.5 percent would be suitable for moderate levels of aflatoxin, temperatures and grain moisture. The quantity of ammonia for various application rates is shown in Table 2 for 15 percent moisture corn.

Treating Small Batches

Small batches of corn in hopper bottom containers may be treated by injecting ammonia at the bottom of the hopper, no ammonia gas recirculation is required if properly sealed. Therefore, corn treated in hopper bottom wagons which are properly sealed normally requires no recirculation of the ammonia even though gaseous ammonia is used for treatment. The corn to be treated must be sealed in a plastic bag which can be placed in a hopper bottom wagon (see Figure 1). One end of the plastic bag (shaped like a cylinder) is placed through the side discharge door of the wagon to allow grain discharge after treatment and allow entrance of a hose in the bottom of the hopper into the plastic bag.

The door of the wagon is lowered on the plastic bag with the hose inside to keep corn in the wagon after the plastic is gathered and tied tightly around the hose. A soda pop can with holes punched in the sides should be placed over the end of the hose to prevent corn from entering the hose. Drop the top portion of the plastic bag over the side of the wagon to allow filling of the wagon with a grain auger. After filling, gather the plastic together and tie it tightly like a big sack, sealing the grain inside. Anhydrous ammonia (gas) can be added through the hose and weighed or measured by reading the percent full gauge on a small ammonia tank. If the ammonia causes freezing in the line or valve, shut off the ammonia supply until it thaws and add the remaining desired ammonia to give the desired rate. After a period of five to seven days, the corn should be sampled and analyzed to measure aflatoxin levels.

Table 2. Quantity of Ammonia at Various Treatment Rates

Anhydrous Ammonia (Gas) (NH ₃)			Aqua-Ammonia (29%) (Liquid) (NH ₄ OH)		
Rate of Application (%)			Rate of Application (%)		
0.5	1.0	1.5	0.5	1.0	1.5
Quantity per bushel (lbs)			Quantity per bushel (fl.oz.)		
0.24	0.48	0.71	14	28	42
Corn moisture increase			Corn Moisture increase (%)		
none			1	2	3



Figure 1. Corn to be treated is sealed in a plastic bag placed in a hopper bottom wagon.

Treatment in Large Batches

Treatment in large batches or in flat bottom containers requires ammonia vapor recirculation for 48 hours. The fan can then be discontinued for the remainder of the treatment except for short operation periods for heat and moisture distribution (and condensation on the plastic). The treatment time varies, depending on grain temperature and moisture (from one to three weeks). If sampling indicates aflatoxin has been reduced to acceptable levels, the return hose can be disconnected and the fan operated to aerate the grain. Aeration in this manner helps remove some of the ammonia smell and makes the corn more acceptable to swine and poultry. Cattle can readily digest the ammonia since urea is used in cattle rations.

The plastic used as a cover must extend under the grain and have a central duct under the center of the grain pile. Laterals consisting of 6-inch diameter perforated plastic drain tile can be connected to a central duct every 24 inches along the central duct and extended at right angles to the central duct to within two feet of the edge of the pile. A flexible return duct can be sealed to the top of the plastic cover. A squirrel cage fan powered by an electric motor can be used to recirculate ammonia from the flexible duct at the top of the pile forcing it under the corn through the central duct underneath (Figure 2). Ammonia can be injected into the pressurized duct beneath the grain pile from the vent of an ammonia tank. Ducts should be sized to keep air velocities in the ducts below 1,000 feet per minute. The fan and motor should be sized to deliver 1/2 cfm per bushel treated.

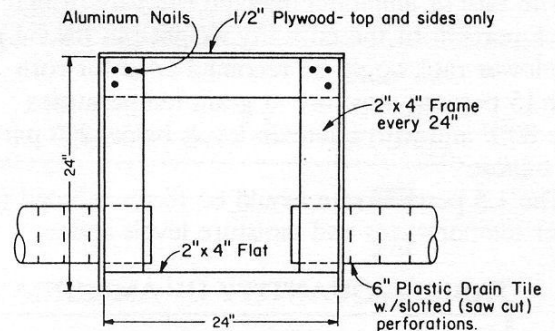
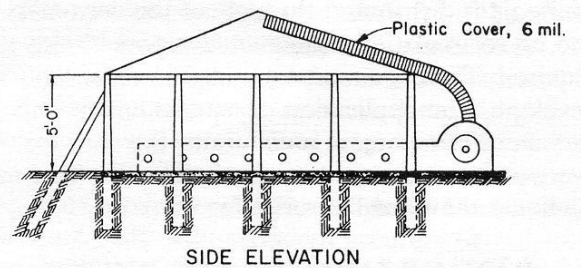
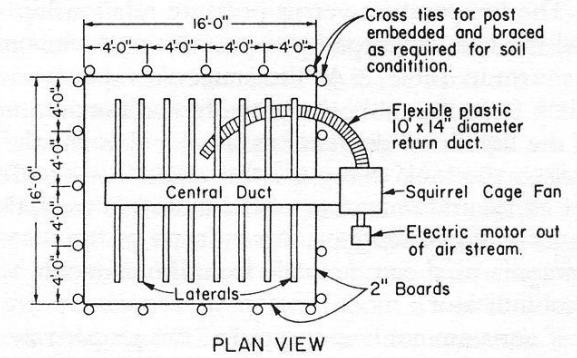


Figure 2. 1200 Bushel Ammoniation Facility

Aflatoxin Reduction in Corn During Harvest and Storage

Aflatoxin has received considerable attention in recent years. Corn, livestock and feed producers and feed processors are aware of problems caused by aflatoxin. It is currently illegal to ship corn interstate that contains more than 20 parts per billion aflatoxin. Such grains have reduced sales and feed value. Molds and aflatoxin can occur in the field before harvest and either is likely to increase after harvest, particularly if sound practices are not followed.

Aflatoxin is caused by the fungus *Aspergillus flavus*. Stress during fungus growth seems to increase aflatoxin levels. It is extremely poisonous to warm blooded animals, even at low levels.

Aspergillus flavus is a very common fungus, and since it occurs so frequently in nature, it can be assumed to be on most grain in the field and in storage. The fungus grows best when the temperature is between 80 and 100°F and humidity is above 80 percent.

Physical Damage to Seed Coat

Damage to the grain seed coat permits easy entrance of molds and fungi, and promotes rapid development of storage rots at high moisture and temperature levels. Aflatoxin can develop within 24 hours in

mold and fungi infected corn stored under these conditions, even though corn was previously free of aflatoxin. Research shows most aflatoxin occurs on corn in broken and damaged kernels and in foreign material.

Harvest to Reduce Aflatoxin

Harvesting must be done very carefully to prevent damage to seed coat and to assure maximum cleaning of grain since damaged seed and foreign material contribute to the development of aflatoxin. The following practices will reduce likelihood of this problem:

1. When corn reaches maturity, harvest immediately and dry mechanically. Harvest should begin when moisture level reaches 28 to 30 percent.
2. Combine should be adjusted for maximum cleaning (adequate air and proper sieve setting). Consider using a grain cleaner at the bin to remove trash before placing into storage.
3. Combine cylinder speed should be slow enough and concave clearance as great as possible to provide adequate threshing. Less damage to seed coat occurs with these settings. Install filler plates between cylinder bars to reduce physical damage.

Grain Handling

Hold high moisture grain in wagons or trucks no longer than six hours. High moisture corn being held for drying should be placed in a holding bin using forced air to keep it cool. Use sound sanitation practices in handling grain. Clean auger wells and pits and around dump stations before and after each use. Physical damage by conveyors or dropping into tall bins should be minimized.

Storage

Check and repair storage bins to prevent moisture leaks from faulty joints or other problems. Bins should be cleaned and debris removed to reduce contamination. An insecticide should be used to treat the bin before filling.

Grain in storage should be aerated when it is 10°F or more warmer than outside air temperature and humidity is below 65 percent. An air flow rate of one-tenth cubic feet per bushel per minute is adequate for cooling grain. Drying fans can be used to cool grain in a few hours when outside air conditions are favorable. Air should be pulled from the top of the bin and exhausted through the bottom to prevent moisture condensation at the top of the grain during aeration. Never add heat during aeration. Operation of aeration fans during summer is not recommended unless hot spots or a musty odor develops. If this occurs, operate the fan during the coolest part of the day for about 10 minutes until the problem disappears or grain can be marketed. Grain held in storage should be inspected and probed every 3 to 4 weeks. Check for insect activity, high temperatures, mold growth or sprouting at the top of the grain.

Dry Properly

Drying temperature and drying time may have an effect on the development of aflatoxin in stored grain. Slow drying with low heat over long periods could promote development of aflatoxin.

Lay-in Bin Drying

Drying corn in deep layers can produce conditions highly favorable for mold development. The drying air temperature for this method is increased only 10 to 20° F above outside conditions. The relative humidity in the top layer of grain remains very high for an extended period of time. These factors are favorable for aflatoxin production. Aflatoxin production can be minimized using the bin dryer by modifying the slow process, layer-in-bin drying method to a batch-in-bin drying system.

Batch-in Bin Drying

Much grain is batch dried in bins. Wet grain is usually placed about 3 to 4 feet deep in a drying bin and hot air (about 140°F) is forced through the grain drying the batch normally in less than 24 hours. The grain is then cooled for storage or cooled by aeration fans in storage. This method can be used when storage is available to unload dryer before putting additional wet grain into the dryer. If the heater is adequate to raise air temperature sufficiently, this method can increase drying rate by a factor of three over the layer-in-bin drying method. Chances of aflatoxin being produced with this system is decreased when higher temperature and faster drying are used. To prevent further fungi and mold growth in storage, dry to an average moisture content of 12 percent.

Column Dryers

Aflatoxin production in column dryers operated at high temperatures (180-200°F) and short drying time (1-2 hours) is very unlikely. This is true for batch or continuous flow column type dryers.

Cleaning Corn to Reduce Aflatoxin

Mold, fungi and aflatoxin levels in corn are normally higher in the fine material commonly referred to as "fines." Removal of the "fines" can reduce aflatoxin levels up to 50 percent. Corn having little fine material, however, would not be improved substantially by cleaning.

Sampling Corn

Samples of corn to be tested for aflatoxin should be taken from several points within the grain mass using a grain probe. Seal samples in a paper bag for shipment. Plastic bags should not be used since they hold heat and moisture, thus creating an environment suitable for mold growth. The following laboratory test can be used for testing shelled corn and mixed feed. The black light is not a reliable test for aflatoxin.

- Minicolum, acetontile extraction
- Thin layer chromatography, acetontile extraction
- Florodensitometer for accurate quantitation
- High pressure liquid chromatography for differentiation and quantitation

Grain Preservatives

Several organic acids are registered for use on high moisture corn. Propionic acid, isobutyric acid, ammonium isobutyrate, etc., are sold under various trade names. Organic acids will prevent *Aspergillus flavus* fungus growth if properly applied to the grain as it is augered into storage; however, these acids will not destroy or remove aflatoxin already present in the grain. Grain treated with acids can be used only for livestock and poultry feed. Grain treated with these acids is corrosive to metals and should not be used in metal bins unless the metal is protected.

Insects in Stored Grain

Insects spread mold, contaminate grain and produce conditions favorable for mold growth. Insects capable of breaking the pericarp either before or after harvest can produce favorable conditions for aflatoxin development.

Control insect activity by using proper sanitation, residual bin sprays or fumigation. Label directions on the container should be followed closely since some of these materials improperly used can be dangerous.

Conclusion

Corn treated with ammonia turns dark because the sugar (altrose) is caramelized and the grain temperature increases about 10°F at the time of treatment. The ammonia breaks the double bond oxygen ring between carbon and oxygen, rendering the toxin inactive. Aqua-ammonia or anhydrous ammonia can be used effectively.

The ammonia treatment is effective and inexpensive and it can be done on the farm at low cost by sealing the grain in plastic. The corn must be completely sealed to prevent the ammonia from escaping into the atmosphere. The ammonia may be added in the gaseous form or liquid form (aqua ammonia) but must be recirculated if applied as a gas into flat bottom containers. No ammonia recirculation is necessary in small batches if the corn is properly sealed into a hopper bottom wagon.

No heat exchangers to prevent freezing of anhydrous ammonia lines are necessary. If the tank or lines begin to freeze, a plastic cover can be added to give a greenhouse effect. After thawing, additional ammonia can be added. A total of 0.71 pounds of anhydrous ammonia per bushel is required under the worst conditions. Corn treated with ammonia has a tendency to stick together if the corn is above 17 percent moisture. Sticking does not occur when corn is treated at lower moisture levels although treatment at lower moisture levels and colder temperatures slows the process.

Cattle can digest the ammonia in the corn much like they do when urea is added as a feed supplement. Swine and poultry, on the other hand, have no way to utilize the ammonia remaining in the corn and may be reluctant (at least initially) to eat the corn containing the ammonia smell. Dairymen have traditionally benefitted the most from ammoniation since dairy feed should be below 20 parts per billion in aflatoxin to prevent aflatoxin being detected in the milk.

The FDA has not approved the ammoniation process and treated corn cannot be legally shipped out of state. It is also important to follow good safety practices and have water ready for flushing the eyes and skin if an emergency occurs. Spark or flame must not be allowed to come in contact with ammonia. Motors used to drive fans for recirculation of ammonia must not be exposed to direct contact with the ammonia. Ammonia reacts with copper, and a motor in the air stream could cause an explosion.



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