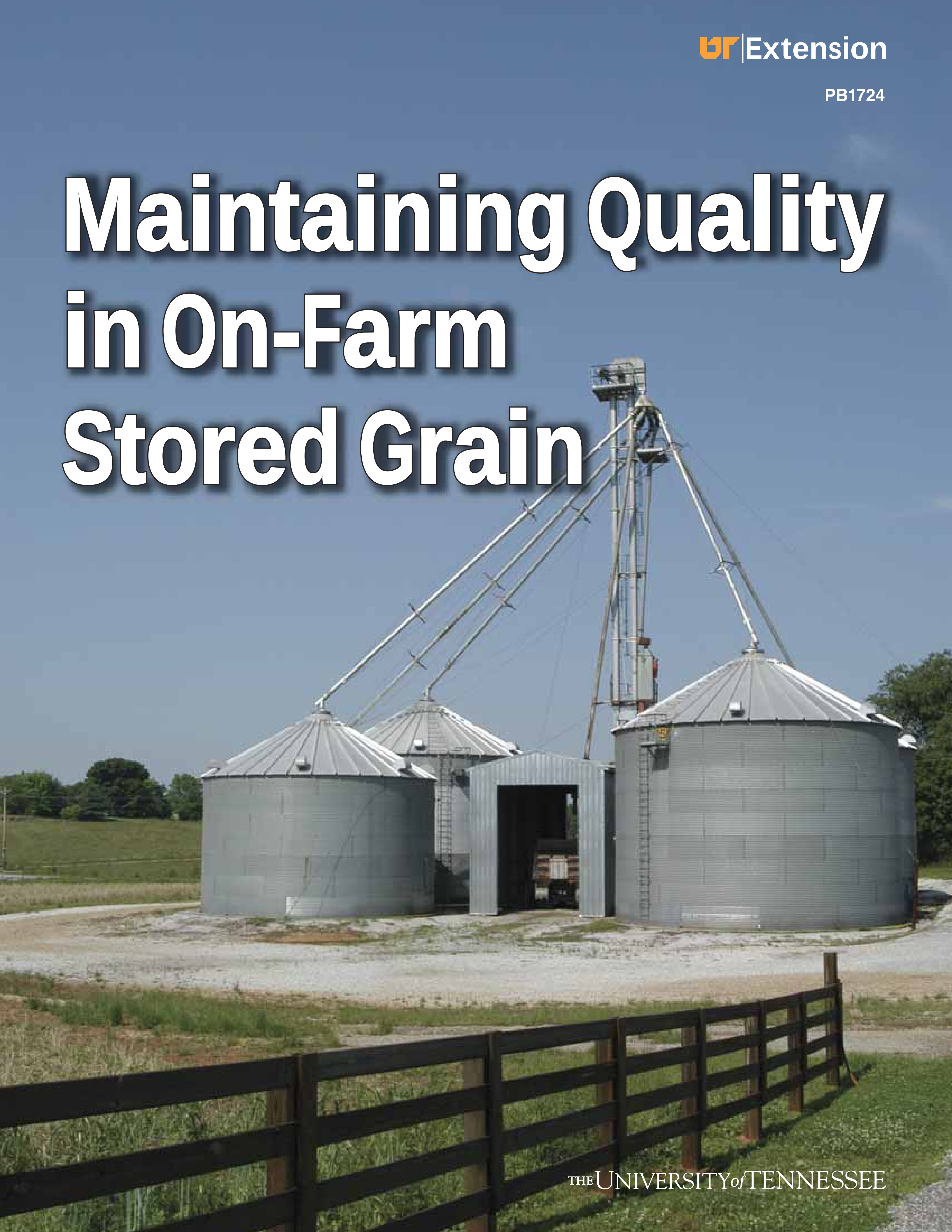
UT Extension

PB1724

Maintaining Quality in On-Farm Stored Grain



THE UNIVERSITY of TENNESSEE

Contents

Special thanks to:
Wanda Russell and Richard Maxey, UTIA Marketing and Communications, for editing and graphic design.

Maintaining Quality in On-Farm Stored Grain

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Introduction

Industry concerns over grain quality, along with increased production of specialty, identity-preserved and food-grade crops, have placed increased focus on grain quality and storage issues. Most damage that occurs during storage is caused by molds and insects. Grain spoilage occurs as microorganisms feed on the nutrients in the grain. As they grow and develop, these microorganisms produce heat, which increases the temperature of the surrounding grain. This heating may result in hot spots. If the temperature and moisture in the grain are just right, the major mold species Apergillus, Fusarium and Pencillum may produce mycotoxins such as aflatoxin, fumonisin, DON and zearalenone. These mycotoxins can cause serious illness and even death when consumed by humans or livestock. The presence of mold does not mean that mycotoxins will be present, but rather the potential exists for their development with the right combination of temperature, grain moisture content and storage time. Even more frustrating is the fact that the absence of mold does not guarantee that mycotoxins are not present.

This is because the growth of the mold may not be extensive enough to cause visible damage, but nevertheless, it can still produce toxins.

Economic losses caused by stored grain insects can be measured in several ways. When the grain is sold, costly discounts are levied for insect damage. More importantly, infested grain results in dissatisfied customers and a poor reputation in marketing channels. Left untreated, insect infestations will eventually lead to other storage problems. Insects give off moisture that can cause grain moisture contents to increase enough to create a mold problem. Mold activity will in turn raise temperatures and result in an increased rate of insect reproduction. Greater numbers of insects create more moisture, and the cycle is repeated at an ever-increasing rate. Management of field insect pests often receives more attention than storage pests. However, storage losses are often equal to or greater than field losses due to dockage and contamination of the grain.

Grain quality will not improve during storage. At best, the initial quality can only be maintained. Once grain is stored, the quality depends on your control and management of the storage system. Molds and insects need adequate food, moisture and temperature to survive and reproduce. Since food is always available in stored grain, grain moisture and temperature must be maintained at levels that are detrimental to mold and insect growth.

Grain Moisture and Temperature

Grain moisture content and temperature interact to affect storage risks. Even the best management practices will not keep grain from spoiling if the moisture content and temperature are too high. For example, grain that is held continuously at 75 degrees F and 25 percent moisture content will deteriorate more in four days than 15 percent moisture grain held at 60 degrees F will in 250 days. As little as a 0.5 percent moisture increase can mean the difference between safe storage and a damaging invasion by storage fungi.

Favorable moisture and temperature levels must exist for fungi to grow. Recommended storage moisture contents depend on the length of time that grain will be stored, and are given in Table 1. These recommendations refer to the wettest grain in the bin, not the average moisture content. These moisture contents may be too high if the grain is poorly managed in storage. Reduce the recommended moisture contents by 1 percentage point when storing low-quality grain. This includes immature grain, severely cracked and damaged grain, and grain subject to previous insect or mold activity. The influence of grain temperature and moisture become especially important in long-term storage.

Grain moisture content and temperature also influence insect population growth and reproduction. At low moisture levels, insects that feed on stored grain have a more difficult time obtaining the water necessary for growth and development. Optimum feeding and reproduction for most insect species typically occur between 70–90 degrees F. As grain temperatures drop below 50 degrees F, most visible insect activity, including feeding, ceases. Most insects do not enter hibernation at these low temperatures, but do become less active. Insects that don't feed at these lower temperatures will use up stored energy reserves and eventually die of starvation. Since the insects are not reproducing, their numbers will begin to slowly decline.

To reduce the incidence of molds and insects, cool and dry the grain immediately after harvesting. It is important to monitor the moisture content both before and during drying. Take samples from several locations within the bin to be sure the moisture content in all locations is at safe levels.

S.L.A.M.

Appropriate actions taken as the crop goes into storage and during the storage period will minimize the chance of problems. Maintaining the quality of grain in storage requires an integrated approach that incorporates a number of tools and practices rather than relying on a single "big gun" approach to treat a problem after it occurs. Relying on a single tool to take care of a problem is an approach that simply will not work. The S. L. A. M. management strategy is an integrated approach that producers can use to maintain the quality of grain in storage. S.L.A.M. stands for Sanitation, Loading, Aeration and Monitoring.

	Moisture Content % Wet Basis		
Storage Period	**Corn**	**Wheat**	**Soybeans**
Sept. - Oct.	14	13.5	12
Nov. - Mar.	15	14	13
Apr. - May	14	13	12
June - Aug.	13	12.5	11

Table 1. Recommended grain moisture content for safe storage.

Sanitation

Grain crops stored on the farm have a limited storage life due to molds, insects, rodents and other pests. Proper sanitation before the harvest season begins will help minimize the chance of problems occurring during storage. Some good sanitation practices include the following:

- Remove old grain from combines, truck beds, grain carts, augers and any other equipment that is used for harvesting, transporting or handling grain. Even small amounts of insect-infested or moldy grain left over from a previous harvest can contaminate a bin of newly-harvested grain.
- Remove any spilled grain, weeds, tall grass or other vegetation around the bins to reduce the likelihood of rodent or insect infestations.
- Inspect the bin roof and sides, inside and out, for cracks, loose or missing bolts, and rust or other corrosion. Repair all leaks and holes to prevent water and rodent damage. Place a light inside the bin and inspect from the outside at night to help you find any cracks or holes that may have been missed.
- Clean grain storage facilities thoroughly before filling to eliminate existing insect and mold infestations. Remove all old grain, sweep walls, floors and ledges and remove and clean augers and boots.
- Remove all debris from fans, exhaust vents and aeration ducts. If possible, clean under perforated floors to remove any accumulation of dust and fine materials that can harbor insects and rodents.
- After cleaning and repairing bins, sanitize the walls, floors, underfloor and roof areas inside and out with an approved residual spray. Pesticide applications without adequate cleaning are generally a waste of money and time. See Extension PB1395 ***Insects in Farm-Stored Grain - Prevention and Control*** for more details on grain bin sanitation.

Loading

Good-quality, clean, sound grain is much easier to store and market than cracked and broken grain. Broken grain and foreign material, or fines, create two problems in stored grain, especially when they accumulate in pockets in the bin. First, broken kernels and trash create a haven for molds and insects. Broken kernels will mold three to four times faster than whole kernels.

Broken grain is also more susceptible to insect attack, because many of the common grain insects are secondary feeders and only feed on broken or cracked kernels and other materials, not sound kernels. Second, accumulations of fine grain particles, weed seeds and other foreign material form dense pockets in the center of the bin (Figure 1). Airflow from drying or aeration fans tends to go around these dense pockets of fines so they dry and cool more slowly. These pockets often develop into hot spots that result in spoiled grain. Good management practices can

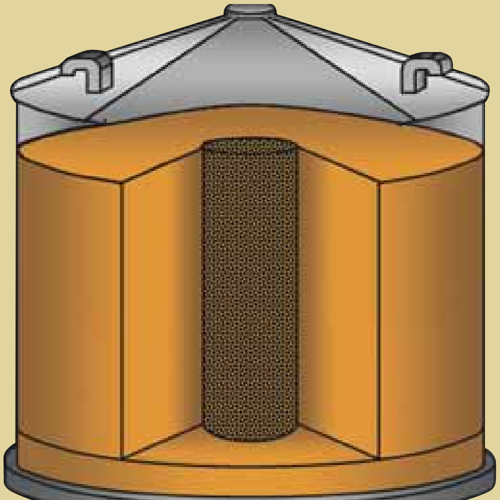

Figure 1.
Trash and fines form dense pockets in the center of the bin.

Weeds and tall grass around the bin can harbor insects.

Don’t overfill the bin.

reduce storage risks from accumulations of trash and fines.

To help assure that only high-quality grain goes into storage, the following management practices are recommended:

Before Loading the Storage Bin

- Properly adjust your combine to the manufacturer’s specifications to minimize grain damage during harvest and to maximize the removal of trash and fines.
- Operate augers at full capacity to reduce wear and grain breakage. With variable incoming flowrates, reducing auger speed can keep the auger operating at full capacity. Another option is to add a hopper over the auger intake, keeping it full. Be sure that all safety shields and auger intake grates are kept in place and in good working order.

Loading the Storage Bin

- Do not mix new grain with old grain, because this will be a potential source of mold and insect infestation of the new grain.
- Cleaning grain before loading into storage bins reduces the amount of foreign material and greatly improves its storability. Unfortunately, cleaned grain may have no greater market value. Fines add weight to the marketable grain. Unless fines are causing lower grades or serious storage problems, cash-grain farmers may lose money by cleaning grain unless the cleanings can be sold to a livestock producer or grain elevator.
- A good management practice in bins equipped with center unloading augers is to periodically unload some of the grain to remove any trash and fines accumulated in the center of the bin. This is often referred to as “coring.” During filling, run the unloading auger at least daily or more often if needed to remove the peaked grain (Figure 2). The goal is to form an inverted cone with a diameter in the range of 5 to 10 feet. The grain that is removed can be mixed with other grain and put back into the bin.

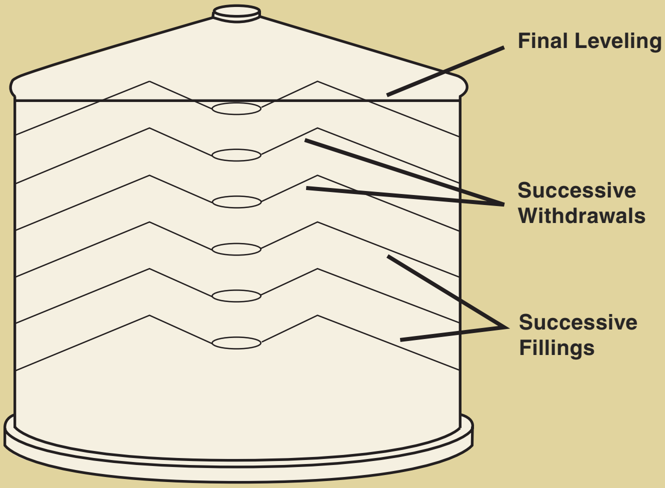

Figure 2.
Coring a bin of grain to redistribute the trash and fines.

Coring does not remove the trash and fines, but repeated unloadings help redistribute much of this material that normally would accumulate in the center of the bin. After the bin is full, the grain surface should be leveled.

Leveling the Grain Surface

Most dry grain peaks at an angle of 18 to 20 degrees when filling the bin from the center. Although peaking adds more storage capacity, these peaked areas increase airflow resistence.

Air follows the path of least resistance and tends to flow around the grain located in the peak (Figure 3). You will have to operate a fan about 50 percent longer to cool an overfilled bin compared to a similar bin with the grain leveled and only filled to the eave. Peaking the grain also makes it more difficult and dangerous to monitor during storage.

Managing the grain during storage is much easier when the grain is leveled after the bin is filled (Figure 4). Three methods are commonly used to level the grain. The first is unloading the center core immediately after filling. By unloading 200 to 300 bushels, the overfilled portion of the bin, as well as some of the trash and fines in the center core, is removed. The second method is using a gravity or mechanical grain spreader. A properly adjusted and operated grain spreader can leave the top surface of the grain

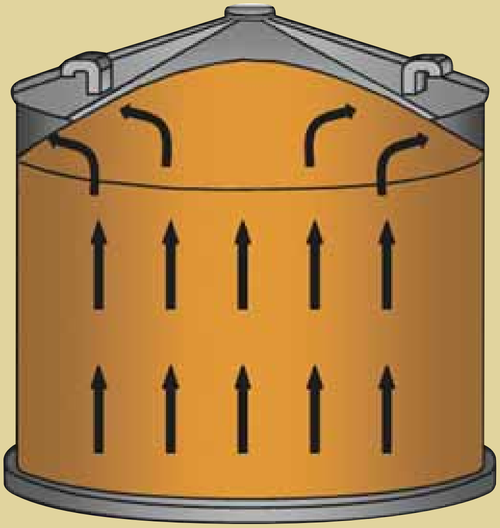

Figure 3.
Peaked grain causes uneven airflow through the grain.

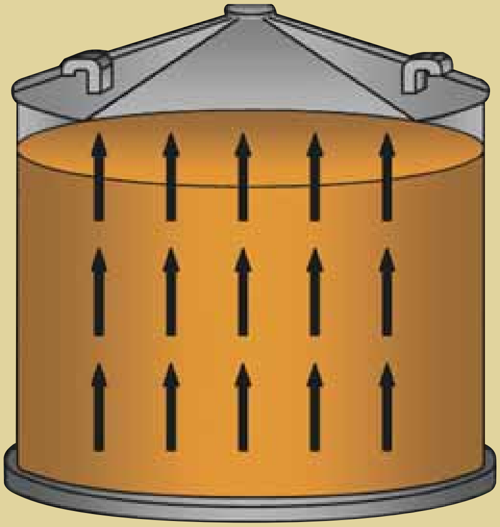

Figure 4. A level grain surface is easier to manage.

Peaked grain is harder to manage.

level and evenly distribute the fine material throughout the bin. One problem with using a grain spreader is that the grain tends to be packed tighter in the bin. Although this might seem a plus, since more grain can be stored in the bin, packing increases airflow resistence, which reduces airflow. When using grain spreaders, the depth of grain may need to be adjusted to ensure that you have adequate airflow when running aeration fans.

The last method is leveling the grain by hand. This method is seldom used because it is often very hot and dusty inside a grain bin. If you level a bin by hand, you need to take some precautions. Never enter a grain bin alone. Have at least two people at the bin to assist in case problems arise. Do not enter a grain bin without stopping the auger first and then using "lock-out/tag-out" procedures to secure it. Use a key-type padlock to securely lock the switch for the auger in the off position. Attach a tag to the locked switch so that other people involved can positively identify it. Always wear a respirator capable of filtering fine dust particles.

Aeration

Moisture Migration

Millions of bushels of dry grain spoil each year because grain temperatures are not controlled. When grain is stored at safe moisture levels but is not aerated, moisture movement, commonly called moisture migration, can develop from one part of the grain mass to another. Moisture migration is caused by significant temperature differences that develop within the grain mass. Grain is a good insulator, which means that heat loss from grain is relatively slow compared to other materials. For this reason, when grain is placed in a bin in the fall, the grain near the center of the bin tends to maintain the temperature at which it came from the dryer or field. On the other hand, the grain along the bin wall and along the top and bottom of the bin tends to cool near the average outside temperature. As the outside temperatures get colder, the differences in temperature between the grain in the center of the bin and along the outside walls become more pronounced.

Air currents develop as the grain and air near the bin walls cool. Cooling causes the air along the outer walls to become heavier and settle very slowly toward the bin floor (Figure 5).

The air moves along the floor to the center area of the bin, then rises slowly through the warm center grain mass. Since warmer air can hold more moisture, it absorbs moisture from the grain as it rises. When the warm, moist air rises through the top layer of cooler grain, the air is cooled, loses its water-holding capacity and begins condensing moisture on the colder grain near the surface. The grain along the surface absorbs this water, which causes

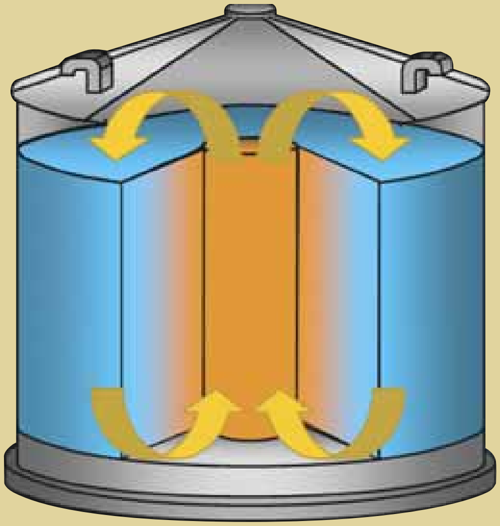

Figure 5.
Natural air currents developed during winter conditions in non-aerated bins.

the moisture content to increase. This increase in grain moisture content, coupled with warmer air temperatures in the headspace, creates an environment that enhances mold and insect growth. This surface moisture change can occur even though the grain was initially stored at safe moisture contents. The reverse situation occurs during the summer months, when the grain along the bin walls warms faster than in the center. As the air along the bin wall rises, it pulls air down through the center of the bin. In this case, moisture is redistributed to the bottom center of the grain mass.

Problems caused by winter moisture migration often become obvious in the spring when outside air temperatures begin to warm. Often, minor moisture migration problems develop into severe spoilage if allowed to continue developing for several months during late winter or early spring. The first indication of trouble is usually damp or tacky-feeling kernels at the grain surface, followed by the formation of a crust. As the center of the bin seals over, the rising air moves farther away from the center and continues to condense moisture near the surface on the cold grain. If the problem is not corrected, the entire top surface of the bin can crust over, as shown in Figure 6.

Aeration greatly improves the "storability" of grain by changing the temperature of the grain in response to seasonal temperature changes. Aeration is not a grain-drying system, but a management tool that can be used to reduce mold development and insect activity and to prevent moisture migration. Aeration involves moving low volumes of air through the grain to control and maintain uniform temperatures throughout the grain mass. Begin aeration in the fall when the average monthly outdoor temperature is about 10 - 15 degrees F lower than the grain temperature. Proper aeration will require several cooling cycles. If the crop is put into storage at 85 degrees F, the first cooling

Aeration is a management tool that greatly improves the storability of grain.

cycle will cool the grain to 55 - 65 degrees F, the second to 40 - 50 degrees F and the third to 35 - 40 degrees F (Table 2). Grain held through the winter should be warmed in the spring and held at about 60 degrees F through the summer.

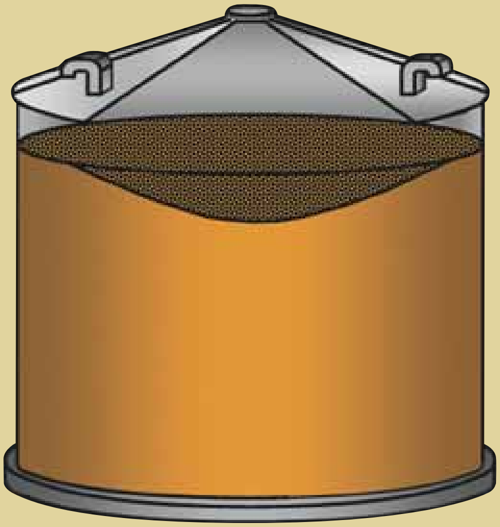

Figure 6. Grain spoilage caused by moisture migration.

Table 2. Target storage temperatures.

Months	*Temperature (°F)*
Sept.	55 - 65
Oct	55 - 65
Nov	40 - 50
Dec - Feb.	35 - 45
April	60

An aeration cycle moves a cooling or warming front through the grain in the same direction as the airflow. A common question is whether the airflow should be upwards (pressure system) or downwards (suction system) through the grain mass. From the standpoint of aeration system performance, the effect of airflow direction is negligible. However, from a management standpoint, upward airflow is preferred, since the top of the grain mass will be the last region to change temperature when a cooling or warming front is moved through the bin. This makes it easier to determine if the front has moved completely through the grain.

How fast the cooling or warming front moves completely through the grain depends on the airflow rate (cfm/bu), the number of hours the fans are operated and the time of year. A rule of thumb is that it takes 150 hours of aeration in the fall at an airflow rate of 0.1 cfm/bu to completely move a cooling front through the grain mass (Table 3). At 1 cfm/bu it takes only 20 hours. When changing grain temperatures, run the fan continuously until the cooling or warming front has been moved completely through the grain. A commonly expressed concern is running aeration fans during rainy or humid weather. The cooling front moves through the crop about 50 times faster than a wetting or drying front, so only a small fraction of the crop is rewetted during an aeration cycle, even when the humidity of the air is very high. However, if several days of foggy or high humidity weather are expected, aeration can normally be delayed until the weather improves. The effects of operating the fan during damp conditions usually are more than offset by the time the fan is operated under more favorable conditions.

Table 3.
Estimated aeration cooling and warming cycles (hours).

Airflow cfm/bu	*Aeration Cycles (hours)*		
	Fall	*Winter*	*Spring*
1/10	150	200	120
1/4	60	80	48
1/2	30	40	24
3/4	20	27	16
1	15	20	12

You can estimate when a cooling front has passed through the crop by measuring the temperature. Place a thermometer 6 to 12 inches into the grain at the top of the bin. When the cooling front has passed through the grain mass, the temperature reading will drop. Check the temperature at several locations. Automatic controllers are now available that will run aeration fans as necessary to cool or warm the grain to the desired temperature.

Aeration Management

Learn to use aeration in terms of grain temperature control, not grain moisture control. The following aeration management tips will help you maintain the quality of your grain in storage.

- The most common mistake is to stop running the aeration fan before the cooling or warming front has moved through the entire grain mass. This can lead to condensation and crusted layers of spoiled grain in the bin.
- As soon as cooling or warming is complete, stop aerating. Otherwise, significant changes in moisture content can occur if substantially more air is moved through the grain than is required for a temperature change.
- Cover the fan when not operating. This limits excessive cooling in winter, rapid warming in the spring and excessive warming in the summer. Moisture may condense on the aeration ducts if warm moist air is allowed to contact the cold grain near the ducts. Also, covering the fan helps keep water, debris and rodents out of the aeration system.
- If "top crusting" occurs, the surface should be stirred to break up the crust or, in extreme cases, the crust should be removed. Aeration should be started immediately.

Monitoring

Failing to monitor grain conditions throughout the entire storage period is a mistake that many producers make. Regular inspections are essential if mold and insect activity are to be detected early. A small area that starts to heat or otherwise go out of condition can quickly get out of control and spread within the bin.

How often you need to check the grain in storage will vary with the time of year, the initial condition of the grain and how often the grain is aerated. Generally, grain should be inspected at least once a month during the winter and every two weeks during the spring, summer and fall. Grain checking is extremely important during the summer, because grain is being held at higher temperatures and aeration conditions are less favorable than during the rest of the

Grain probes and insect traps are useful monitoring tools.

year. Grain temperatures should be checked and recorded during each inspection. Without temperature records, it is difficult to tell whether elevated grain temperatures are caused by normally occurring outside temperatures or by heating due to mold activity. Use a deep bin probe to obtain samples at different locations in the bin to determine the moisture content, the amount of trash and fines and the general condition of the grain. An accurate moisture tester is required to determine actual moisture contents. Inexpensive moisture meters or one that has been in use for many years can give inaccurate readings under many conditions. You can check the accuracy of your tester by checking readings with your local elevator.

When checking your bins, look for:

- Condensation on the grain surface, crusting, wet areas, molds and insects.
- Leaks or condensation on the bin roof.
- Non-uniform temperatures in the grain mass, pockets or layers of high-moisture grain, molds and insects.
- Musty or sour odors. Spoiled grain gives off a detectable odor, but in most cases, the spoiling grain must be near the surface of the grain and the grain must have undergone considerable spoilage before you can detect any odor. Generally, if you can smell a musty odor, a problem is already well underway.

Any problems that are found need to be evaluated and corrected as soon as possible. This may include cooling with aeration, further drying or fumigation for insect control.

Summary

Maintaining the quality of grain in storage requires an integrated approach that incorporates a number of tools and practices. Storing only clean grain at the proper moisture content and temperature, sanitizing the bin before loading, checking the grain condition regularly and correcting problems before they get out of hand are critical management strategies that must be implemented to prevent grain deterioration and possible economic loss.

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PB1724-2.5M-6/05 (Rep) E12-4315-00-004-05 05-0413