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Harvesting, Drying, and Storing Grain Sorghum

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Introduction

Grain sorghum (milo) has been successfully produced in many areas of Kentucky and can be grown in alternating years with soybeans to replace corn in a crop rotation cycle. For most of the past 20 years, it has ranked fourth in production of all grain crops grown in the state and was valued at $1.16 and $1.53 million in 1999 and 2000, respectively. Rotating milo with soybeans can help control soybean cyst nematodes and other pests that suppress yield. It can provide higher yields than corn in dry years, especially on sandy soils. The feed/energy value of milo is similar to corn, so it has been used successfully in balanced rations for beef, poultry, and swine and as a feedstock for ethanol production (Hamman et al., 2001). In fact, the 2002 Farm Bill (USDA, 2002) encourages an increase in the production of grain sorghum because of its use as an ethanol feedstock and the current national interest in reducing foreign oil imports.

Increased production of grain sorghum will be accompanied by an increased interest for information on harvesting, drying, and storing this unique crop. Allowing the crop to dry in the field to safe storage moisture levels can lead to significant yield losses. Some grain dryers may need to be modified to reduce the inherent threat of a fire when drying milo because of slightly higher levels of trash that often comes in with the grain. A safe storage environment is essential to protect the crop from damage by insects, molds, and rodents and the subsequent economic loss that can result.

This publication outlines proven practices for successful harvesting, drying, and storage of grain sorghum. The following suggestions are offered to help preserve the quality of grain sorghum during and after harvest to assure that product quality is maintained until the crop is delivered for sale and ultimately processed into feed, food, or fuel products.

Harvesting

Grain sorghum kernels are highly exposed to the elements of nature (like wheat). Consequently, it is highly susceptible to pre-harvest losses from birds, insects, molds, and unfavorable weather. Unlike wheat or corn, milo does not normally dry in the field to a moisture level that is suitable for direct marketing (14.0%) or safe storage (13.5% or lower) until after a killing frost or the application of a desiccant chemical. Consequently, artificial drying is usually required unless dry weather prevails for several days after the crop reaches physiological maturity (moisture content of ~30%).

Like corn and wheat, milo can be harvested at moderately high grain moistures (between 18 to 22%) if sufficient drying capacity is available. Harvest losses often exceed economic levels outside this range, as shown in Table 1. A five-step procedure for measuring grain sorghum harvest losses is provided by Taylor (1998). A slight modification involves counting the total number of seed (loose kernels and those still attached to the grain head) in a 10-square-foot area behind the combine. Divide the total number of seeds by 200 to calculate harvest losses in bushels per acre (20 kernels per square foot are equivalent to a loss of 1 bushel per acre, assuming a seed size of 15,600 seeds per pound). Harvest losses should be measured at three locations in different yield-producing areas of the field to obtain an estimate of average total losses. If they exceed 5% of total yield, reduce ground speed or adjust the gathering, threshing, separating, or cleaning mechanism to minimize machine losses. Refer to the operator's manual for specific adjustments and evaluate them individually to optimize harvesting.

Table 1. Harvest losses (% of potential yield) for grain sorghum at different moisture levels. (Univ. of Delaware, 1985)

Grain moisture, %	Harvest losses, %
30	11.2
25*	10.0
20	8.7
15*	12.5
10	16.3

* Interpolated.

Control harvest losses by setting the combine according to the manufacturer's recommendations before going to the field and by making minor adjustments as needed during harvest to match field and crop conditions. Pay particular attention to ground speed to control gathering losses and to machine settings for the threshing mechanism (cylinder/rotor speed and clearance), separator (chaffer and sieves), and cleaner (fan speed). Routine lubrication and maintenance schedules should also be followed for optimal combine performance.

Standing grain sorghum can be harvested with a conventional sicklebar header. Stalks should be cut as high as possible without losing grain heads. Pick-up type guards are recommended if the heads are drooping or stalks are lodged, especially on wide rows (30 inches). A combine speed of 2.5 to 3.0 miles per hour will normally reduce header losses to a minimum.

Set the cylinder/rotor speed and concave/stationary bar clearance to separate seed from the head without overthreshing. Because grain sorghum seeds crack easily, reduce the cylinder speed below that used for wheat, but run the rest of the machine at a normal speed. A general rule is to set the concave clearance at about 1/2-inch in the front and 3/16-inch at the rear. Some combine manufacturers recommend removing some of the concave bars to prevent damage to the seed.

Grain sorghum stalks are usually much wetter than corn stalks and are more likely to be chopped up and delivered to the grain tank. Prevent stalk pieces from entering the tailings conveyor by keeping the chaffer extension closed slightly. Also keep stems from catching and choking the straw walkers and chaffer sieve. Watch this area closely for matted material because it can lead to excessive grain loss from the back of the combine. Several studies have shown an important link between combine operator attention and machine losses. Expect to make slight machine/operator adjustments when soil or crop moisture levels change between fields to minimize mechanical seed damage and trash intake.

Table 2. Static pressure for various depths and airflow rates for grain sorghum. (ASAE, 1997)

Grain depth, ft	Airflow rate, cfm/bu 0.1	0.5	1.0	3.0	5.0	10.0
	Static pressure, inches of water					
1	0.00	0.01	0.0	0.06	0.11	0.23
2	0.01	0.04	0.08	0.26	0.45	1.02
3	0.02	0.09	0.19	0.61	1.09	2.54
4	0.03	0.16	0.33	1.12	2.04	4.92
5	0.05	0.26	0.53	1.81	3.36	8.29
6	0.07	0.37	0.8	2.70	5.08	12.79
7	0.10	0.51	1.07	3.80	7.23	—
8	0.13	0.67	1.42	5.11	9.84	—
9	0.16	0.85	1.82	6.67	12.95	—
10	0.20	1.06	2.27	8.46	—	—
11	0.24	1.29	2.78	10.52	—	—
12	0.29	1.55	3.36	—	—	—
13	0.34	1.83	3.99	—	—	—
14	0.39	2.14	4.68	—	—	—
15	0.45	2.47	5.44	—	—	—
16	0.52	2.83	6.26	—	—	—

Drying

Corn drying systems can be used for grain sorghum although longer exposure times are to be expected for the same amount of moisture removal. This is because the smaller seed offers higher resistance to airflow than shelled corn, which results in lower airflow rates for the same depth of grain. The rate and extent of drying are primarily dependent on the amount of airflow and the moisture-holding capacity of the air, respectively.

Airflow rate is the quantity of air that is moved through a quantity of grain in a given amount of time. For grain drying and aeration applications, airflow rate is usually described in units of cubic feet of air per minute (cfm) per bushel of grain, or cfm/bu. Typical airflow rates for grain drying range between 1 to 10 cfm/bu for in-bin dryers and 75 to 125 cfm/bu for high speed column dryers. In contrast, airflow rates for full bin aeration systems typically range between 0.1 and 1.0 cfm/bu.

The amount of resistance to airflow is described as static pressure and is usually measured in inches of a water column. For a given type of grain, static pressure increases with grain depth, airflow rate, and concentration of trash/fine particles that are smaller than seed size. Most of the trash and foreign material found in grain sorghum is generally larger than the seed, so its presence tends to offer less resistance. The static pressure of clean grain sorghum at various depths and airflow rates is shown in Table 2.

The Minnesota Extension Service has developed an extremely useful computer program to assist engineers and designers with fan selection for various grain drying and aeration applications (Hanson et al., 1996). This program can be used to estimate the airflow rate (in cfm/bu) through most grains at various depths for any existing fan-bin combination. More than 200 commercially available fans can be selected to evaluate their performance for on-farm and commercial bins. Since most vane axial fans deliver very little air at static pressures above 4.0 inches of water, this is an obvious upper limit for grain drying systems with these types of fans. In comparison, most centrifugal fans can deliver moderate amounts of airflow at static pressures up to 7 inches of water, while a few are rated as high as 10 inches of water. Often the best operating condition for in-bin drying of milo is to limit grain depth between two-thirds to three-quarters of that used for corn to provide adequate airflow rates, safe drying times, and efficient fuel use. Conversely, economical drying depths for corn can be between 1.3 and 1.5 greater than those used in systems that were originally designed for milo.

Expect longer drying times for grain sorghum than for corn in high temperature automatic batch or bin dryers when the same amount of water is to be removed. Decrease the discharge rate from continuous flow dryers for longer exposure times for grain sorghum than for corn. Limit the drying air temperature to 110°F for sorghum seed, 140°F for milling/processors, and 180°F for livestock feed.

Drying air temperature and relative humidity set the moisture-holding capacity of air and ultimately the final moisture content of grain. Sufficient exposure to different temperature and relative humidity conditions will dry milo to the moisture shown in Table 3. Obviously, grain moisture decreases with increased air temperature and lower relative humidity. For example, milo will reach a moisture content of about 13.9% when dried with a continuous supply of air at 70°F and 70% relative humidity, which is a typical average outside air condition for the month of September in Kentucky. This moisture level should be adequate if grain will be cooled to 40°F or lower within a few weeks after drying and sold before warm weather the following spring.

Table 3. Equilibrium moisture content (% w.b.) of grain sorghum at various temperature and relative humidity levels. (ASAE, 2001)

Temp. °F	Relative humidity, % 10	20	30	40	50	60	65	70	80	90
30	6.6	8.4	9.7	11.0	12.1	13.3	14.0	14.7	16.3	18.6
40	6.5	8.2	9.6	10.8	11.9	13.1	13.8	14.5	16.1	18.4
50	6.3	8.0	9.4	10.6	11.7	12.9	13.6	14.3	15.9	18.2
60	6.2	7.9	9.2	10.4	11.5	12.7	13.4	14.1	15.7	18.0
70	6.0	7.7	9.0	10.2	11.4	12.6	13.2	13.9	15.5	17.8
80	5.9	7.6	8.9	10.1	11.2	12.4	13.0	13.7	15.3	17.6
90	5.7	7.4	8.7	9.9	11.0	12.2	12.9	13.5	15.1	17.4
120	5.6	7.3	8.6	9.8	10.9	12.1	12.7	13.4	14.9	17.2

In contrast, if an extended period of cool, wet weather prevails during drying—with average temperature and relative humidity of 60°F and 80%, respectively—milo will only dry to about 15.7% moisture, which is too wet for safe storage. Given this condition, the crop should be dried with heated air to increase storability. For example, a 10-degree rise in temperature will reduce the relative humidity by nearly 20 percentage points when the temperature is increased from 60° to 70°F. Thus, in this case, low temperature drying with average conditions of 70°F and 60% will reduce the moisture content of milo to about 12.6%, which should be adequate for storage up to one year, provided the crop is properly aerated and monitored.

Slight modifications may be required for some dryers to accommodate the higher amounts of trash and fines that are typically brought in with grain sorghum that has not been cleaned. Extended air intake hoses are often used on automatic batch and continuous flow dryers to prevent trash and fines from passing through the heating section of these dryers; otherwise, a FIRE HAZARD MAY EXIST! Producers who plan to include several hundred acres of milo in a long-term crop rotation system should consider installing a grain cleaner to avoid the drying and storage problems associated with trash and fines.

Storing

All grain stores best in a clean, cool, and dry environment. Clean grain should be held so that the relative humidity of the air space between grain kernels is no more than 65%. The highlighted column in Table 3 shows various moisture and temperature conditions for this humidity level. For example, the air space in the grain mass of a bin of milo that has been dried to 14% moisture and cooled to 30°F will have a relative humidity of 65%. If this bin remains full until the following summer, grain next to the outside wall will warm to near 80°F, and the air space in that zone will reach humidity levels of about 72%, which is an undesirable condition because it is sufficiently warm and moist to promote mold growth and insect activity. The most cost-effective method of limiting the relative humidity of the air space in the grain mass is to control grain moisture (through proper drying) and temperature (by aeration during storage).

Storage Strategy: S.L.A.M

Control of grain moisture is the first step toward successful storage. Other steps incorporate an integrated pest management strategy that includes sanitation, bin loading, aeration, and monitoring strategies (S.L.A.M.) proven to reduce storage problems (Maier et al.,1997). This approach involves a combination of sequential steps from pre-harvest through post-harvest that are designed to control grain storage pests and the economic losses associated with their activity.

Sanitation

Sanitation involves the thorough cleanout of all equipment that will harvest, transport, or handle grain as it moves from the field to the final storage unit and ultimately to the point of sale. Combines, grain carts, trucks, pits, hoppers, conveyors, dryers, and storage bins should all be thoroughly cleaned to protect the new crop from contamination with mold or insect-infested grain from other crops. Dust masks or similar personal protection equipment (PPE) should always be worn when cleaning equipment to protect lungs and breathing passageways from exposure to dust and mold spores. The area around storage bins should be mowed or sprayed with a herbicide to remove tall grass or weeds that can harbor insects and rodents. Spilled grain around pit hoppers, bin doors, and all other areas should be removed immediately after harvest to eliminate ready access of this food supply.

Bin Loading

Clean grain will always store better than grain with fines, trash, and weed/foreign material. If cleaning is not feasible, fill bins with grain spreaders so that fines and trash will not be concentrated in a central core in the middle of the bin. If a spreader is not used, remove the center core of grain after filling the bin, and place this material in a separate bin that will be unloaded first for sale or feeding. Do not store milo in the center peak of a bin for extended periods. This area offers more resistance to airflow, which renders it susceptible to rapid heating and spoilage.

Aeration

Use the FANS model to determine the airflow rate at different depths of grain for each bin in the storage facility. Estimate the number of hours needed for a cooling cycle to pass completely through the grain mass by dividing 15 by the airflow rate in cfm/bu, as shown in Table 4. To facilitate aeration management, small fans should be operated continuously until the cooling cycle has moved completely through the grain mass. Ideally, operators should strive to select a 3- to 5-day period when average temperatures are predicted to be in the target range. Large fans should also be operated when outside conditions match the target range and can be run intermittently.

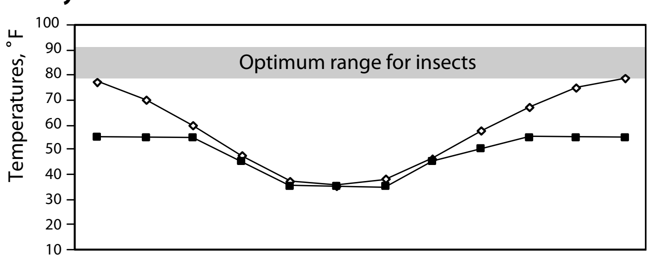
Aerate milo once each month during the fall to maintain uniform temperatures in the bin that are within 10° to 15°F of the average monthly temperatures. Refer to Figure 1 for target storage temperatures throughout the year. Cool grain to between 35° and 40°F by December, and seal fans with plastic or a similar material to block wind-driven air currents through the grain that can lower grain temperatures below desired levels.

Table 4. Estimated time required to move a cooling cycle through stored grain at different airflow rates.

Airflow rate, cfm/bu	Number of hours	Mode of operation*
0.1	150	C
¼	60	C
½	75	C
¾	20	I
1.0	15	I

* C = continuous fan operation; I = intermittent fan operation.

Figure 1. Average monthly air temperatures (AMT), optimum temperature range for insect development, and target temperature for stored grain (GT) throughout the year in Kentucky.



Month	A	S	O	N	D	J	F	M	A	M	J	J
AMT	77	70	60	47	37	35	38	46	58	67	75	78
GT	55	55	55	45	35	35	35	45	50	55	55	55

Monitoring

Monitoring grain sorghum for insect or mold activity is important during storage to be sure the crop remains in good condition. Considering that the crop value in a single storage bin can be worth tens of thousands of dollars and that spoiled grain can amount to a 5 to 10% loss, the recommendation that grain managers inspect stored grain on weekly or semimonthly intervals seems reasonable.

Temperature cables can provide valuable information for isolated spots inside grain bins, especially where handheld grain/temperature probes cannot collect samples or penetrate the grain bulk. It is important to realize that temperature sensors may not detect isolated warm areas or "hot spots" within 12 inches in any direction (Maier, 2002). Similarly, thorough manual inspections provide valuable information about the quality of stored grain near the surface but have severe limitations in deeper regions of the bin unless a vacuum probe (Seedburo, 2000) is used, which is expensive and cumbersome.

Safety

When inspecting stored grain, adhere to the same general safety precautions that are prescribed for working in an enclosed space.

- All workers should read Cooperative Extension publication *Aeration, Inspection, and Sampling Stored Grain* (AEN-45) to review the potential hazards of flowing grain and to learn of recommended methods for a safe inspection.
- In general, stored grain inspectors should be knowledgeable of the risks involved and allow enough time to perform the job safely.
- Workers should always be sure that the unloading auger/conveyor system is turned off and locked out before entering a bin.
- Workers should inform others in the area that a bin inspection is taking place and post signs to notify anyone who may arrive on the site after an inspection begins.
- Personnel should work in pairs for safety, with one person remaining outside the bin and in view of the person inside the bin at all times.
- The person entering the bin should wear a body harness attached to a rope that is firmly secured to the inside ladder or other solid fixture.
- A dust mask or other appropriate PPE is recommended during an inspection of stored grain to protect lungs and breathing passageways from exposure to dust and mold spores.

Summary

Grain sorghum production is expected to increase in Kentucky during the next few years because of its ability to compete with corn in feed, food, and fuel value and in crop rotation systems with soybeans. Proper harvesting, handling, drying, and storage techniques are important to maintain grain quality as the crop moves from the field to the market. Milo should be dried uniformly and thoroughly to a moisture level that matches the anticipated storage period to assure product quality. Conscientious equipment sanitation, bin-loading techniques, aeration management strategies, and monitoring during storage should all be employed for controlling stored product pests. More information is available from the references listed, from county offices of the University of Kentucky Cooperative Extension Service, and from UK's Biosystems and Agricultural Engineering Department <www.bae.uky.edu>.

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