On-Farm Grain Drying Methods

Sammy Sadaka, Ph.D., P.E.
Assistant Professor - Extension Engineer

Karl VanDevender, Ph.D., P.E.
Professor - Extension Engineer

Griffiths Atungulu, Ph.D.
Assistant Professor - Grain Processing Engineering

Introduction

When grain is harvested from the field, it contains dry matter and water. While water is necessary for plant growth and grain production, excess moisture after grain maturity can lead to storage-related problems. Grain moisture content is expressed as a percent of the grain weight. For example, 100 pounds of 13% moisture content rice contains 13 pounds of water and 87 pounds of dry matter rice. Grain moisture content and temperature play a key role in determining safe storage life (see https://www.uaex.uada.edu/publications/pdf/FSA1058.pdf). As a rule, dryer grain and cooler temperatures increase safe storage durations. In contrast, wetter grain and warmer temperatures increase the potential for pests, insects, mold and fungi to reduce grain quality and market value. Therefore, the primary objective of grain drying and storage is to manage the temperature and moisture of the air around the grain to minimize grain quality and market value losses while holding grain for better market opportunities. Maintaining grain quality requires drying the grain to safe moisture content levels after harvest followed by lowering and maintaining the grain temperature within a few degrees of ambient air temperatures.

Traditionally, on-farm grain drying and storage has seen limited use in Arkansas. However, recent changes in agricultural markets and technological advances have made grain production more attractive resulting in more producers and more production. This increased supply is associated with a larger grain price swing between harvest and non-harvest periods. Therefore, in addition to more control of harvest timing, there are potential economic advantages to on-farm drying and storage. Accordingly, several Arkansas producers indicated their interest in exploring the possible techniques of on-farm grain drying and storage. This fact sheet provides an overview of the basics of on-farm grain drying and storage methods.

Grain Drying Basics

Storage Moisture Content

The first step in drying grain is determining the desired, or target, grain moisture content level. Under drying grain reduces safe storage time, increases the potential for quality losses and increases the likelihood of high moisture price dockages upon sale. Over drying grain reduces income due to increased drying costs. In addition, since grain is usually sold on a weight basis, one of the expenses involved in drying grain is the "cost" of the weight loss that occurs during the drying process. This weight loss by drying is referred to as "shrink" and is expressed as a percentage of the original quantity before it is dried. Shrinkage should be considered to accurately determine the total cost of mechanical drying. Shrinkage tables provide bushel weights for various moisture content levels of grains (see https://www.uaex.uada.edu/publications/pdf/FSA-1078.pdf). When choosing the desired target moisture content, safe storage time, grain shrinkage and buyer's requirements should be considered.

Grain conditioning by drying and cooling to target ranges should begin immediately after harvest. If possible, avoid leaving grain in carts and buggies for more than a few hours or overnight. As indicated earlier, grain temperature and moisture content dictate how quickly grain quality and market value are reduced. Drying and cooling freshly harvested grain will delay spoilage and must begin within 24 hours and preferably within 12 hours after the harvest.

Equilibrium Moisture Content

The moisture in grain creates vapor pressure. In a like manner, the moisture in the air around the grain also creates vapor pressure. Moisture moves from areas of high vapor pressure to areas of low vapor pressure. This moisture movement continues until the vapor pressures in the grain and air are equal. The point at which vapor pressure in grain and air are equal is called the Equilibrium Moisture Content (EMC). The EMC is dependent on three factors: air temperature, air relative humidity around the grain and grain type. EMC values for grain decreases as air humidity decreases or air temperature increases (see https://www.uaex.uada.edu/publications/pdf/FSA-1074.pdf). Thus, grain drying will occur as long as the EMC is less than the current grain moisture content. If the EMC is greater than current grain moisture content, drying will not occur. Instead, additional water will be added to the grain bin. Water will increase the potential for mold and needs to be removed as soon as possible.

KEY CONCEPTS

- Moisture moves from high to low vapor pressure areas.
- Grain drying occurs when the vapor pressure in the grain is greater than the vapor pressure of the air surrounding the grain.

If the current air conditions will not result in grain drying, the easiest way to adjust EMC is by heating the air. Heating air lowers the air relative humidity and thus lowers the EMC and decreases drying times. As a result, after heating air the new relative humidity must be measured or calculated before determining the new EMC.

Temperature and Humidity

As indicated earlier, air temperature and humidity determine EMC level and thus the drying capacity of the air around the grain. Since ambient air temperatures and humidities fluctuate over time, the EMC and drying potential of air also fluctuates. Therefore, in drying systems that use ambient air (with or without low levels of supplemental heat), air temperature and humidity should be monitored and used to determine when the drying system should be operated. If mismanaged, drying opportunities could be missed or moisture could be added back to the grain environment increasing storage risks and wasting the energy to run fans again to re-dry.

The ability to heat drying air increases the opportunities to dry grain and provides more control over the grain drying and storage process. If the EMC of ambient air will result in grain drying, adding heat will reduce drying time and lower the final grain moisture content. The reduced drying time is usually desirable. However, if mismanaged, there is an increased risk of over drying grain. There is also energy cost to run fans and heaters. If the EMC of ambient air will not result in grain drying, adding heat can provide drying that otherwise would not take place. As a result, the decisions of what type of grain drying/storage system to install and when to run fans and/or heaters become a process of balancing risks and economic inputs.

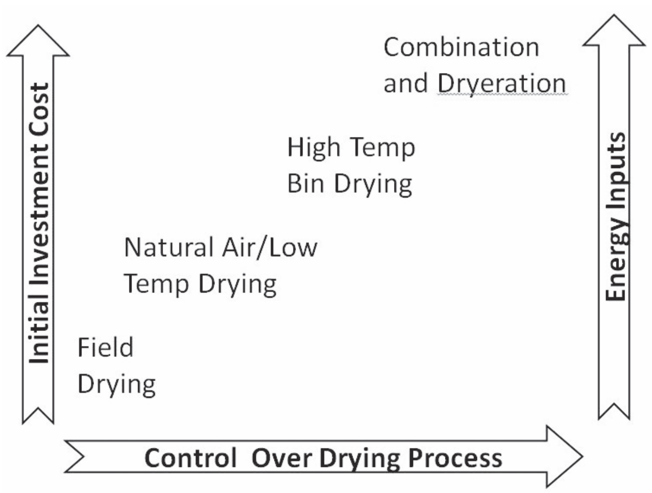
For manually controlled systems, the temperature for determining EMC should be an average temperature over the drying period. The relative humidity should be the average expected during the drying period. However, several companies make automated grain drying controls which measure grain moisture, air temperature and air humidity. These automated controls can take much of the "guesswork" out of grain drying. Temperature can be read with a thermometer in the plenum or on the farm. Ideally, temperature and relative humidity should be measured on farm, but local weather information has been used in the decision-making process with acceptable results.

Evaporating moisture from grain requires energy in the form of heat. In general, it takes 1,100 BTUs of heat to vaporize one pound of water at 100% efficiency. Heat energy can be supplied by the natural heat content of air or by supplemental heating. The amount of moisture that air can absorb and transport as it moves through the grain column is dependent primarily on EMC along with some influences from air velocity, the distance the air travels and grain moisture content. As air moves through the grain column, it absorbs moisture and thereby loses some or all of its drying capabilities.

Grain Drying Options

Grain drying strategies can be divided into the following approaches: field drying, natural air drying, low temp drying, high temperature drying, and combination or dryeration. Allowing the grain to dry in the field is the most widely used method. In many cases, partial field drying is often used in conjunction with post-harvest drying to reach target storage moisture content. Natural air/low temp grain drying is best described as filling or partially filling bins with freshly harvested grain, then running fans to force air through the bins until the desired moisture content is achieved. High temperature drying is either conducted in the bin or within a pass dryer. Air is heated to high temperatures and forced through the grain until the grain dries. Combination and dryeration is done by partially drying grain with high temperature dryers, and then the remainder of the drying process is done with low temperature air and fans. Each method has its advantages and disadvantages. In general, more drying process control reduces potential risk. However, an increase in control is usually associated with increased investment costs and energy costs (Figure 1).

FIGURE 1. General relationships among management control, initial investment cost and operational energy costs for various grain drying approaches.



Field Drying

Grain drying begins in the field after the grain is fully mature. A layer of tissue is formed between the seed and the plant which blocks additional moisture and nutrient inputs from the plant. At this point the maximum grain quality and yield are set. Once the grain matures and the layer of tissue is formed between the seed and the plant, the sun and air can remove moisture and dry grain at a rate of ½ to 1 percent per day. Once moisture reaches near storage goal level, drying slows. Drying using this method is very common. Most producers field-dry grain to a certain moisture content and then harvest and dry further or market the grain at harvest. The disadvantage with this method is the reduced control of the drying process and potential exposure to weather and pests which causes damage. In addition, over drying grain usually increases shatter and losses during harvest. Field drying should be used to manage grain moisture at the time of harvest. The time of year grain reaches maturity and the weather conditions can have a major impact on how quickly the grain will dry to a moisture content acceptable for storage or sale.

Natural Air Drying

Natural air drying is the most common on-farm drying method in Arkansas. It refers to the process in which grain bins are filled or partially filled with grain and then natural air is moved through the grain with fans (Figure 2). This is typically done in bins equipped with a perforated floor, drying fan, grain spreader, sweep auger and unloading auger. Stirring devices may also be added. However, they are not economical for natural air drying systems in most grain-producing areas because over drying is usually not a significant problem. Loading the drying bin may be accomplished by either a portable auger or a bucket elevator. The loading rate should be sufficient to empty a large trailer truck in no more than 2 hours, thus a minimum of approximately 500 bu/h capacity.

As dry (lower vapor pressure) air passes wet (higher vapor pressure) grain, moisture moves from the grain into the air. The addition of water to the air reduces its ability to dry the grain it passes through next. This process continues as the air moves through the column of grain until the air no longer dries the grain, or the air exits the grain. As the fans continue to run, a drying front moves from where the air enters the grain to where it exits the grain. Behind the drying front, the grain is at EMC. Ahead of the drying front, the grain is above EMC. The vapor pressure and flow rate of the air entering the grain determine the formation of this drying front and how quickly it moves through the grain. The air flow rate depends on fan properties as well as the type and depth of the grain. As grain depth increases, air flow rates decrease. Therefore, increasing grain depth slows the drying front and increases the amount of time it takes for all the grain to reach EMC, and the potential for grain quality losses.

A common mistake with natural air drying is to add too much grain to the bin at once. This will increase drying times and delay the grain drying process which increases the likelihood of grain quality losses. Therefore, it is commonly recommend to only add 4-5 feet of grain to a bin at a time. Then avoid adding more grain until the layer is dry. Depending on the system setup, several bins can be loaded alternatively, or the dry grain can be moved to another bin.

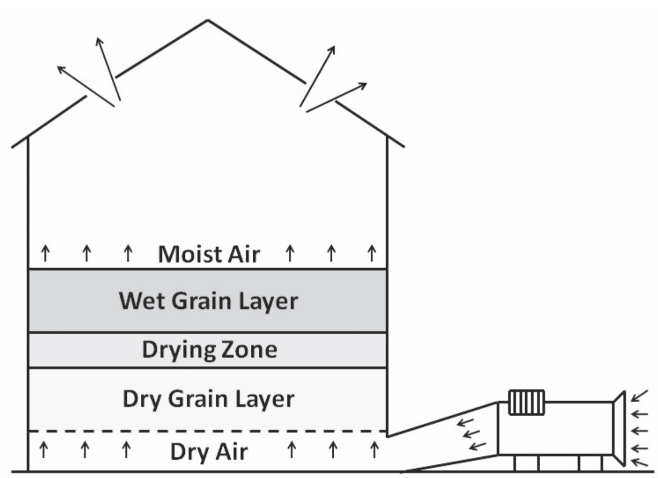
Successful grain drying with natural air is usually the most energy-efficient method of drying. It is also the slowest method and has the greatest potential for grain spoilage. Consequently, natural drying requires the highest level of management if spoilage and/or aflatoxin problems are to be prevented. Much of the risk is because there is little "reserve" capacity for speeding up the drying process in that the inlet air conditions vary with the weather. Typically, the bin is filled only once each harvest season. If spoilage begins, the mid-course corrections are limited to either (1) drying immediately using another drying method or (2) selling before the grain degrades because of unacceptable damage levels.

Low Temperature Drying

Low temperature drying refers to the process in which grain bins are filled or partially filled with grain and then air with little (<10°F) heat added is moved through the grain with fans (Figure 2). This is typically done in bins with a perforated floor or ducts. Usually, electricity is the thermal energy source, hence the term "electric drying" is sometimes used instead of "low temperature" drying. However, LP gas and solar energy may also be used as thermal sources.

The low temperature drying method is assumed to always have potential for drying grain within the accepted moisture contents associated with long-term storage. This is contrasted with natural air-drying where outside air conditions may not allow further drying. When air is heated, its temperature and volume increase, but its moisture level remains

FIGURE 2. Grain bin utilizing natural air/low temperature drying.



constant. This results in a lowering of the relative humidity of the air and allows for a possible net transfer of moisture from the grain to the air. Moisture transfer continues until the grain and air come into equilibrium. In grain drying, the drying fan continuously supplies air as moisture is transferred from the grain and removed from the bin. With low temperature drying, sufficient heat is added so that drying can continue until normally acceptable final moisture contents are reached.

In this method, a perforated floor is required. A grain spreader, under-floor unloading auger and sweep auger usually are included. A stirring device may also be added. Filling the bin may be accomplished by either a portable auger or a bucket elevator.

In low temperature drying, grain is dried and stored in the same bin, thus minimizing handling and labor costs. Generally the comparative total cost for drying decreases as less energy is used to heat the drying air even though more energy is required to operate the drying fans. Thus, successful low temperature drying is relatively economical in terms of energy costs when compared to higher temperature methods. Some of this advantage is lost when electricity is used as the thermal energy source because it is usually more expensive than LP gas on per unit of energy basis.

Successful low temperature drying is defined as drying the grain to a desired moisture content without excessive economic losses through either energy costs or grain spoilage. Potential for drying increases when adding heat to increase the drying air temperature. Unfortunately, the rate of grain spoilage also increases with higher temperature. Thus, low temperature drying is generally restricted to conditions where grain moisture is relatively low, nearly 20% for corn. Low temperature drying has little reserve capacity; that is the system dries grain at a low steady rate that cannot be altered greatly. The dependability of the system is reduced further if solar energy is the heat source.

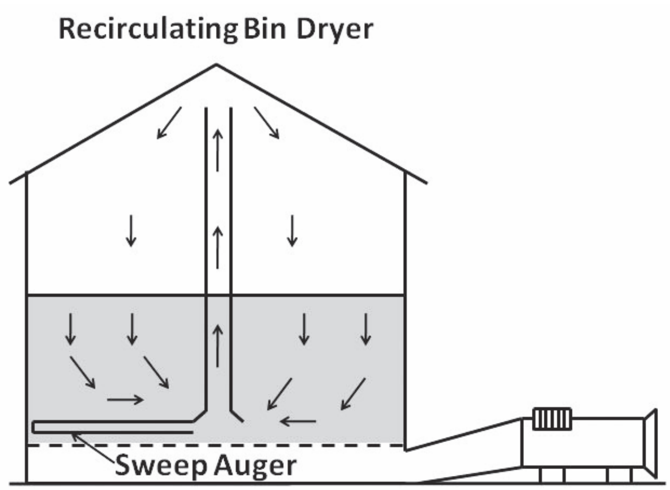
Perhaps the greatest risk associated with low temperature drying is the year-to-year variability of weather. The same drying strategy may not be used every year. Care should be taken to avoid aflatoxin contamination.

High Temperature Drying

High temperature drying is done either in the bin or in a dryer. There are four approaches to high temperature drying: in-bin batch drying, recirculating bin drying, continuous flow bin drying and pass drying. In-bin batch drying is similar to natural air/low temperature drying except that air temperatures are often 120°-160°F and air flow rates are from 8 to 15 cfm/bushel. Drying time is greatly reduced with high temperature drying. However, grain near the floor often becomes excessively dried while the top layer of grain often stays moist. Stirring devices provide more uniform drying and should be considered in conjunction with this method. Stirring also allows for increased batch depth (7-8 feet).

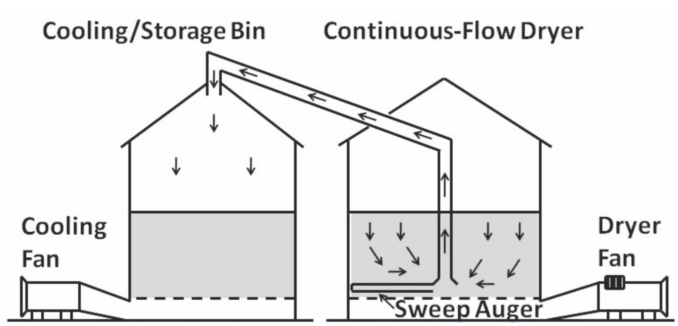
Recirculating bin dryers (Figure 3) are bins that are filled with grain and then the fans and heat are turned on. There is a sweep auger in the bottom of these bins that is activated by temperature or moisture sensors. When a target condition is met, the sweep auger makes one full pass and stops until those conditions are met again. Grain discharged by the sweep auger is placed onto the top of the grain within the bin. Some rewetting of dried grain may take place causing inefficiency concerns.

FIGURE 3. High temperature drying with grain recirculation within the bin.



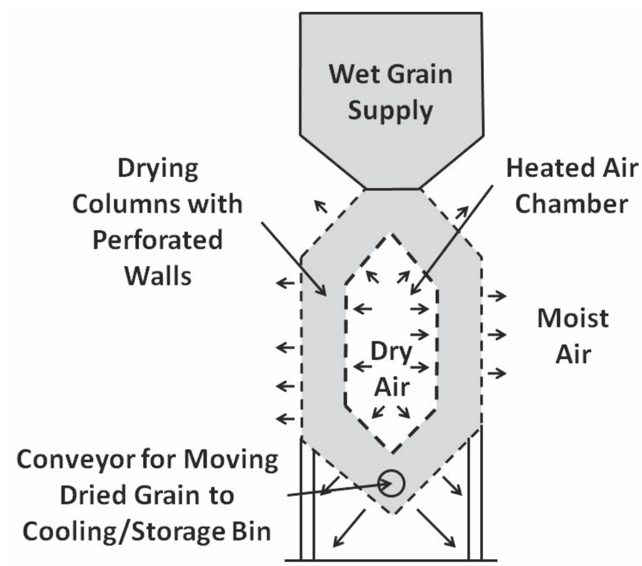
Continuous-flow bin dryers use the same bin setup as the recirculating bins except sweep auger grain is discharged into a cooling bin. High temperature bin drying tends to be more efficient than other high temperature drying processes because the heat is used to dry grain at the drying front which then continues up the grain column to aid in drying before being discharged. (Figure 4)

FIGURE 4. High temperature drying with separate drying and cooling/storage bins.



Pass drying (Figure 5) is typically the fastest method for drying grain. Most grain elevators use some form of pass dryers to dry large amounts of grain quickly. This method requires the highest energy inputs of all drying methods. The biggest benefit to using pass dryers is the large volumes of grain that they can dry. When used in conjunction with a short-term wet grain storage bin, grain can be harvested at a rate that exceeds the capacity of the pass dryer. Then when harvesting pauses, such as at night, the dryer which runs continuously empties the wet holding bin. While pass dryers tend to be the most expensive drying option, they do have the advantage of providing the most control during grain harvesting and drying. Pass dryers are made in several models including some portable models mounted on trailers. Due to the higher temperatures (180° to 220°F) being used, the potential exists to dry the grain too rapidly or too much and cause cracked grain or other problems. However, with proper management, high grain quality can be maintained providing the opportunity to market higher quality grain.

FIGURE 5. Pass dryer diagram.

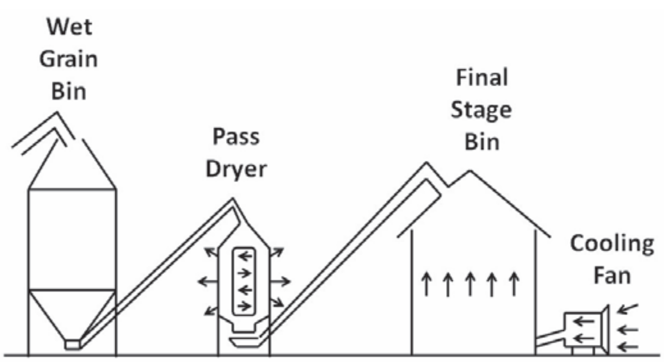


Dryeration and Combination Drying

Combination drying and dryeration (Figure 6) are done by moving grain directly from either a pass or heated bin dryer and into an aeration bin at 1 or 2 moisture points higher than the final desired moisture content. For dryeration, grain is allowed to temper without airflow for 4 to 6 hours. During this time the moisture content within individual kernels equalizes.

Once the first grain that was placed in the bin has tempered, cooling fans are turned on while additional hot grain is added to the bin. The cooling front moves slowly up through the grain so that all grain within the bin has ample time to temper. The cooling fans dry grain the remaining 1% to 2%. This process maintains grain quality better than using high temperature dryers alone. Individual grain kernels redistribute moisture throughout the kernel during the tempering process, which is followed by lower temperature drying reducing stress to individual kernels. Combination drying is essentially the same as dryeration yet it does not have a tempering step. Both of these methods can significantly reduce energy use and increase dryer capacity.

FIGURE 6. Combination and dryeration system diagram. The final stage bin is where the tempering, final drying and cooling take place.



Summary

Production priorities and degree of grain quality control must be considered when choosing a grain drying system. If initial cost is the highest priority, the producer should consider field drying or natural air or low temperature drying. If the main goal of the producer is to get the crop out of the field as quickly as possible, high temperature drying should be evaluated. If grain quality is the priority, dryeration and combination should be considered. As with any investment, costs and returns can be spread over a number of years.

Further Reading

Backer, L. F., R. C. Brook, H. A. Cloud, K. J. Hellevang, B. A. McKenzie, W. H. Peterson, R. O. Pierce, G. L. Riskowski and L. D. Van Fossen. MWPS-13 Grain Drying, Handling, and Storage Handbook. Second Ed. Ames, IA. Mid. Plan Ser. 1988. Print.

Hellevang, K. J. 1994. Grain Drying. North Dakota State University Agriculture and University Extension. November 1994. AE-701. https://www.ag.ndsu.edu/graindrying/publications/ae-701-grain-drying

Hellevang, K. J. et al. MWPS-29 Dry Grain Aeration Systems Design Handbook. Revised First Edition. Ames, IA. Mid. Plan Ser. 2007. Print.

Huffman, C. J., J. H. Pedersen, W. F. Wilcke, P. W. Sacco and C. B. Soballe. MWPS-22 Low Temperature and Solar Grain Drying. First Ed. Ames, IA. Mid. Plan Ser. 1983. Print.

Loewer, O., T. Bridges and R. Bucklin. 1994. On-Farm Drying and Storage Systems. ASABE.

Mckenzie, B. A., and G. H. Foster. 1980. Dryeration & Bin Cooling Systems for Grain. Purdue University Cooperative Extension Service. 1980. AE-107.

Sadaka, S., and R. Bautista. 2014. Grain Drying Tools: Equilibrium Moisture Content Tables and Psychrometric Charts. FSA1074. https://www.uaex.uada.edu/publications/pdf/FSA-1074.pdf

Sadaka, S., G. Atungulu and G. Olatunde. 2016. Safe Grain Storage Period. FSA1058. https://www.uaex.uada.edu.publications/pdf/FSA1058.pdf

Sadaka, S., G. Atungulu and G. Olatunde. 2016. Understanding Grain Shrinkage and Expansion. FSA1078. https://www.uaex.uada.edu/publications/pdf/FSA-1078.pdf

Wilcke, W. F., and K. J. Hellevang. 2002. Wheat and Barley Drying. University of Minnesota Cooperative Extension Service. 1992. FS-05949-GO

SAMMY SADAKA, Ph.D., P.E., is an assistant professor - Extension engineer and **KARL VANDEVENDER**, Ph.D., P.E., is a professor - Extension engineer with the University of Arkansas System Division of Agriculture located in Little Rock. **GRIFFITHS ATUNGULU**, Ph.D., is an assistant professor - grain processing engineering with the Food Science Department located at the University of Arkansas in Fayetteville.

FSA1072-PD-5-2017RV