Overview of On-Farm Natural Air-Drying of Grain

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Introduction

Freshly harvested grains are not always dry to a safe moisture content suitable for marketing or long-term storage. Therefore, they may need artificial drying, such as natural air-drying, to achieve the target safe storage moisture content. Natural air-drying is a technique for drying grain, e.g., corn, rice, soybeans, and wheat, to an equilibrium moisture content with the ambient air. This fact sheet provides an overview of this on-farm natural air-drying technique. It emphasizes the pros and cons as well as some limitations of this technique.

Rationalization of Natural Air-Drying

Natural air-drying is a technique to dry grain by forcing ambient air through the grain mass until the grain attains an equilibrium moisture content with the air. The energy contained within the ambient air is the energy used for reducing the moisture in the grain. The only fossil-based energy supplied for drying using this process is the electricity used to run the fan.

Drying with natural air can be achieved if the air temperature and relative humidity conditions allow a net moisture removal from the grain to the air. The drying fan removes the moisture-laden air from the bin and supplies a fresh quantity of ambient air. The process continues until sufficient moisture has been removed from the grain so that no additional moisture transfers to the air. When this occurs, the grain is said to be in equilibrium with the drying air. The moisture content of the grain when no moisture transfer is possible is referred to as the **equilibrium moisture content (EMC)** for a given air temperature and relative humidity. In addition to temperature and relative humidity of air, the EMC value also depends on the grain type. It should be mentioned, that moisture might be transferred from the air to the grain during natural air-drying if the air EMC is higher than the moisture content of the grain. This process is known as **rewetting**.

Under the two conditions discussed above, assume that air at temperature of 60°F and relative humidity of 70% is being forced through long grain rice. This rice has a moisture content of 18%. According to Table D from *Grain Drying Tools: Equilibrium Moisture Content Tables and Psychrometric Charts* (http://www.uaex.uada.edu/publications/pdf/FSA-1074.pdf), this rice will naturally dry until the moisture content reaches 15.1%. The value of 15.1% is called equilibrium moisture content under these air conditions. If this air is being forced through long grain rice with moisture content of 14.5%, this air will rewet the rice.

System Configuration

A natural air-drying system (Figure 1) consists of a grain bin equipped with a perforated floor and a drying fan. Normally, a grain spreader, a sweep auger and an unloading auger are also included. Stirring devices may be added. However, they are not economical for natural air-drying systems in most grain-producing areas because overdrying is usually not a significant problem. A portable auger or a bucket elevator could be used to load the drying bin. The loading rate should be geared to accommodate the desired harvesting rate and should be sufficient to empty a large trailer truck in no more than two hours, thus a minimum of approximately 500 bushels/hour capacity.

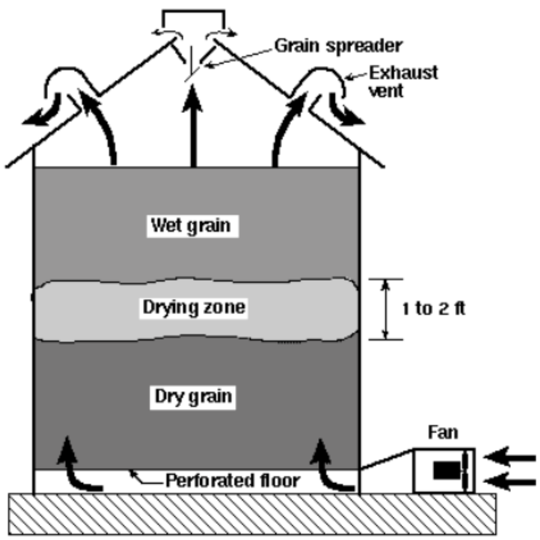


Figure 1. A schematic diagram of a natural-air drying bin (Wilcke and Hellevang, 2002)

Airflow Rate

The rate of drying when using natural air is related directly to the airflow delivered by the fan and the ambient air temperature and relative humidity. Airflow is usually expressed as cubic feet per minute (CFM) of air per bushel of grain; a bushel is being defined volumetrically as 1.25 ft^3. Airflow is influenced by type, quantity and total height of grain in the bin (especially the latter). Airflow is critical because it actually carries moisture from the grain out and into the atmosphere. Grain cleanliness and the extent to which the grain has settled are also critical factors. Most on-farm airflow rates for drying vary from 0.5 to 6 CFM per bushel (Table 1). This is dependent on the initial moisture content of the grain and grain depth.

Table 1. Recommended Airflow Within Grain Bins at Various Grain Moisture Content

Moisture Content (%)	Airflow (CFM per bushel)
11-13	0.5
13-15	1
15-18	2
18-20	3
20-22	4
> 22	6

Grain Bin Fans

Airflow in a grain bin is controlled by the type and size of fans used and the resistance to airflow (static pressure) created by the grain (Table 2). Each type and size of fan delivers a different airflow rate for similar bin conditions. Drying fan performance is specified by the airflow rate the fan will deliver when subjected to a given amount of resistance. Grain moisture content is usually not considered to influence airflow resistance significantly. Airflow rate does increase with increases in fan horsepower. However, a doubling of the desired airflow rate per bushel of grain requires approximately a five-fold increase in fan horsepower, other factors being equal. This makes a relatively large airflow rate in filled bins impractical and severely limits use of natural air-drying in warmer conditions.

Drying fans are rated to move certain volumes (cubic feet per minute) of air at various static pressures. The higher the static pressure, the smaller the volume of air a fan can move. Producers should design a system large enough to move sufficient air through a full bin of grain. Once again,

Table 2. Volume of Air Delivered by a Centrifugal Fan Under Different Static Pressures

	Static Pressure, Inches of Water									
	Free	1	2	3	4	5	6	7	8	9
HP	CFM	CFM	CFM	CFM	CFM	CFM	CFM	CFM	CFM	CFM
5	7,200	7,000	6,700	6,300	5,900	5,500	5,000	4,400	3,800	2,500
7.5	10,850	10,500	10,100	9,400	8,950	8,250	7,500	6,650	5,750	3,750
10	14,500	14,000	13,500	12,500	12,000	11,000	10,000	8,900	7,700	5,000
15	16,750	16,250	15,750	14,750	14,250	13,250	12,250	11,200	10,050	8,000
20	19,000	18,500	18,000	17,000	16,500	15,500	14,500	13,500	12,400	11,000

static pressure increases as grain depth increases. To learn more about grain bin fan classifications, visit the University of Arkansas System Division of Agriculture web site (http://www.uaex.uada.edu/publications/pdf/FSA-1075.pdf).

For instance, there are 4,000 bushels of 19% MC grain in a bin equipped with a 15-horsepower centrifugal fan. With the use of a manometer, the static pressure is determined to be 5 inches of water. Table 2 shows that a 15-horsepower fan will deliver 13,250 CFM of air. By dividing the volume of air by the number of bushels in the bin, it is determined that air is being moved through the grain at a rate of approximately 3.3 CFM per bushel. This air volume meets the requirement of a minimum of 3 CFM per bushel for 19% MC grain.

With a 7½-horsepower fan, the air volume at 5 inches of static pressure would be 8,250 CFM. This volume divided by 4,000 bushels would provide approximately 2 CFM of air per bushel. Under these conditions, the grain depth should be reduced resulting in fewer bushels of grain and a lower static pressure. Attempting to dry at the 2 CFM per bushel rate would mean slow drying and possible deterioration of the grain.

Estimation of Drying Time

Grain-drying time could be estimated through the following three steps.

First: Determine the number of pounds of dry grain (at the desired MC) produced from the wet grain (at the initial MC).

Final weight = (Initial weight) × (100 – Initial MC) / (100 – Final MC) [1]

Second: Calculate the pounds of water that must be removed.

Pounds of water = Initial weight – Final weight [2]

Third: Estimate the drying time.

$$\text{Drying time} = H \times W / (AF \times 1.08 \times (T_{in} - T_{out}) \quad [3]$$

Where:

H is the heat required to vaporize 1 pound of water (1,100 BTU per pound)
W is the excess amount of water per bushel to be removed (pound/bushel)
AF is the airflow rate per bushel (CFM/bushel)
T_{in} is the air temperature entering the drying bin (°F)
T_{out} is the air temperature leaving the drying bin (°F)

The factor of 1.08 is the product of the air specific heat (0.24 BTU/lb °F) times its density (0.075 lb/cubic foot) times the number of minutes per hour (60 min/hour).

Example: Assume that you have 10,000 pounds of rice at MC of 20% that needs to be dried to MC of 13%. Estimate the drying time assuming that air enters the rice bin at 80°F and leaves from the top of the bin at 65°F. The fan is moving 4 cubic feet of air per minute per bushel through the rice, and the weight of rice at 13% MC is 45 pounds per bushel.

Determine the final weight using equation 1.

Final weight = (10,000) × (100 – 20) / (100 – 13)

Final weight = 9,195 pounds = 9,195 / 45 = 204.3 bushels

Apply equation 2 to determine the number of pounds of water to be removed.

Pounds of water = 10,000 – 9,195 = 805 pounds

Therefore, the number of pounds of water to be removed per bushel = 805/204.3 = 3.94 pounds per bushel.

Estimate the drying time using equation 3.

Drying time = 1,100 × 3.94 (lb/bu) / [4 (CFM/bu) × 1.08 × (80 – 65)] = 66.9 hours

Thus, it would take 66.9 hours to remove 3.94 pounds of water from a bushel of rice. To dry any number of bushels will require 66.9 hours as long as an airflow rate of 4 CFM per bushel is maintained. It should be mentioned that drying time estimates are quite dependent on outside air temperature and humidity. Thus, they should be used as a rough guide unless a constant temperature decrease through the rice is maintained.

Don’t Run the Drying Fan Continuously

Running the aeration fan continuously has been a common practice for decades. In the past, however, no one was fully aware of grain moisture conditions in the grain bin. There also was a persistent feeling that there must be times when drying was occurring and times when it was not. Some producers also stated that fans should be continuously running to avoid the collapse of the drying front and to prevent the formation of a crust layer.

Research has demonstrated that turning fans off under some weather conditions is an acceptable practice. If air being forced through grain has higher EMC than the moisture content of grain, air will rewet the grain, which could lead to grain spoilage. Also, forcing high temperature air through wet grain will reheat the grain providing the optimum conditions that contribute to grain deterioration. It is also obvious that turning the fan off will conserve energy.

Researchers stated that when the drying fan is turned off, the temperature and moisture of the grain remain almost constant in the majority of cases or in some cases slowly change.

Economic Considerations

Natural air-drying and storage systems are very economical as long as all the grain can be dried successfully in a single bin without extending the harvest time adversely. It is the least costly drying method if the grain can be dried successfully. The variable cost of drying is primarily associated with the operation of the drying fan. Successful natural air grain drying results in a high-quality product.

However, the primary economic consideration is whether the grain can be dried successfully before the allowable storage life (AST) is reached for grain in the topmost layer. To learn more about the *Safe Grain Storage Period*, visit the University of Arkansas System Division of Agriculture web site (http://www.uaex.uada.edu/publications/pdf/FSA1058.pdf). The relatively slow drying rate associated with natural air-drying requires that grain be brought from the field at a relatively lower moisture content. When harvesting is delayed to allow additional field drying, harvest loss also increases, resulting in economic loss. Some of the energy efficiency advantages are offset because electricity to power the drying fan is more expensive per unit of energy than liquid petroleum (LP) gas, the usual source of thermal energy for drying. If substantial spoilage due to fungi (mold) that can lead to aflatoxin contamination occurs, the economic losses are tremendous when compared to the savings associated with the increased efficiency of drying. Also, if additional bins are needed, drying fans and other associated equipment must also be duplicated, thereby reducing the economic advantage of this method.

Advantages of Natural Air-Drying

- Successful grain drying with natural air is usually the most energy efficient method of drying using fossil energy.
- Natural air-drying requires relatively little direct labor except to level the grain surface in the bin. Ensure that safe bin-entering measures are taken should you decided to enter a bin.
- The bin is filled only once each harvest season.
- Grain quality is high if dried successfully. This method is best suited to single-bin systems.
- Success of using this drying method increases as temperature during harvest decreases.

Disadvantages of Natural Air-Drying

- Natural air-drying is the slowest method and has the greatest potential for grain spoilage.
- It requires the highest level of management if spoilage and aflatoxin problems are to be prevented.
- Major effort should be made to inspect the grain regularly for spoilage and insect infestations.
- Natural air-drying is a high-risk and management-intensive form of drying.
- It has little reserve capacity for speeding up the drying process in that the inlet air conditions vary with the weather.
- The success of the system is very dependent on the weather and field drying of the grain.
- It is not preferable for relatively warm and humid areas.
- 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.

System Performance

Ambient air temperature and relative humidity vary during the harvesting season. This becomes especially important over the long drying periods associated with natural air-drying. The drying time required when using natural air must be considered as it relates to the potential for spoilage. Later in the season, the air temperature-relative humidity combination may reach a point at which the EMC corresponding to this combination is above that of the grain. In this situation, little drying (or perhaps even rewetting) of the grain will occur if further drying is attempted.

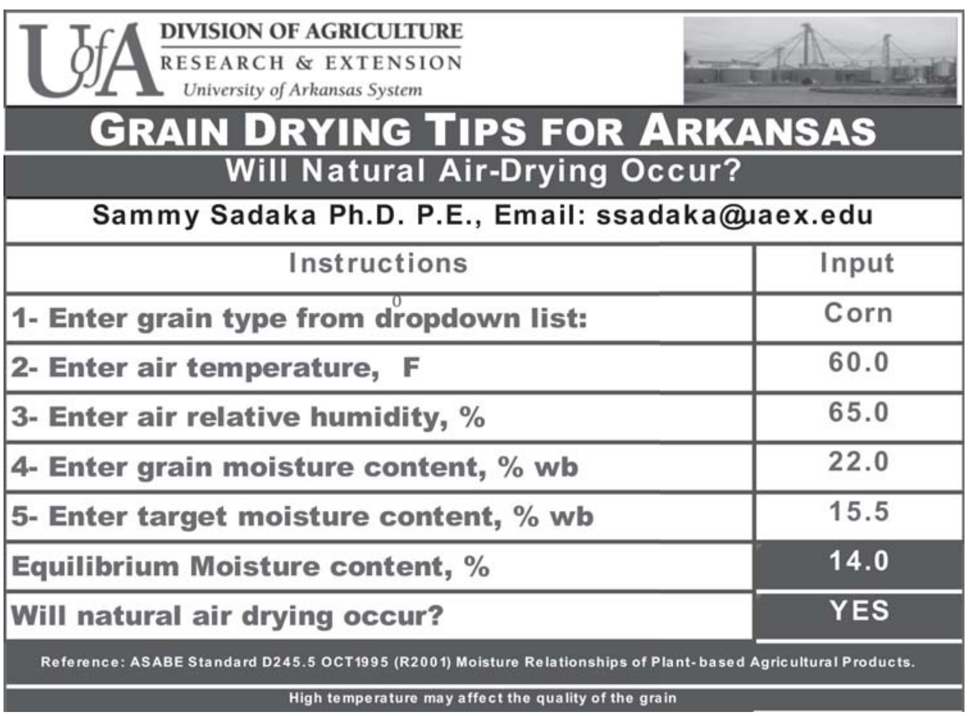
The probability of drying grain successfully with natural air improves if layers of grain are added periodically over the harvest to maximize airflow per undried bushel. If the desired harvest rate is sufficiently high, bin filling may have to be rotated if spoilage and the occurrence of aflatoxin are to be avoided. If the desired moisture content of corn, for example, after drying is to be close to but no higher than a certain value, say 13%, a range of actual temperature and relative humidity values may be used. As mentioned earlier, by definition, natural air-drying does not require the direct burning of fossil energy for heating the air. However, the inefficiency of the drying fan and motor add heat to the drying air. The friction and turbulence produced when air is forced through a fan results in an air temperature increase. The heat gain from air compression is approximately 0.75ºF for each inch of static pressure increase. In addition, the heat gain from air flowing across motor housing, which is mounted on fan wheels in axial flow fans, adds between 0.75ºF and 1.0ºF. This increase in temperature lowers the air relative humidity, thereby increasing its drying capacity and decreasing the grain-air equilibrium moisture content. Recapturing the heat provided by the drying fan makes natural air-drying an even more efficient utilizer of energy assuming the grain can be dried safely. The added heat from the fan will increase drying potential.

Natural Air-Drying Decision Tool

One frequent question asked by producers during the grain-drying season is "Will natural air-drying occur under today's conditions?" Once again, if there is an increase in grain moisture content, the grain may lose its value with the extra moisture from the damp air. Alternatively, in other situations, if natural air-drying is capable of drying grain, it is a waste of energy and money to heat the air. Therefore, producers are looking for simple tools to assist them in grain-drying decisions. Consequently, a web-based calculator was developed to provide a user-friendly tool for producers and county extension agents that simplifies making an informed decision related to keeping the fan on or turning it off. To download and access the web-based calculator, click on the following link: http://tinyurl.com/goaql7r. After downloading and accessing the web-based calculator, the user will see a screen similar to the one shown in Figure 2.

The user should update the spreadsheet by following the instructions and entering the five required inputs. These include (1) grain type (from the dropdown window), (2) air temperature, (3) air relative humidity, (4) grain moisture content, and (5) grain target moisture content. After entering the five inputs, updated values will appear in the output cells. These include (1) equilibrium moisture content and (2) will natural air-drying occur? A supportive decision showing "Yes" or "No" will appear.

An example was created to practice using the web-based calculator. Assume that a producer harvested corn with a moisture content of 22.0% wet basis. The target moisture content is 15.5%. The current air conditions are as follows: air temperature is 60°F and air relative humidity is 65%. Should the producer utilize natural air-drying under these conditions? Figure 2 shows a snapshot of the web-based calculator. In this case, the producer can use natural air for corn drying.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GRAIN DRYING TIPS FOR ARKANSAS

Will Natural Air-Drying Occur?

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Instructions	Input
1- Enter grain type from dropdown list:	Corn
2- Enter air temperature, F	60.0
3- Enter air relative humidity, %	65.0
4- Enter grain moisture content, % wb	22.0
5- Enter target moisture content, % wb	15.5
Equilibrium Moisture content, %	14.0
Will natural air drying occur?	YES

Reference: ASABE Standard D245.5 OCT1995 (R2001) Moisture Relationships of Plant-based Agricultural Products.

High temperature may affect the quality of the grain

Figure 2. A screen shot of the spreadsheet

References and Further Resources

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