

On-Farm Drying and Storage of Soybeans

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Arkansas farmers harvested more than 3.1 million acres of soybeans in 2013. With a state average of 43 bushels/acre, Arkansas soybean production reached 133 million bushels. Soybean producers are increasingly interested in on-farm drying and storage due to the various advantages they offer. For example, producers can afford to harvest soybeans early at higher moisture contents than normal to reduce the possibility of harvest losses. Additionally, they may harvest soybeans at faster rates if daily harvesting hours can be extended. Moreover, on-farm storage may provide marketing flexibility and advantage during the soybean selling process.



Figure 15-1. Newly harvested soybeans.

Since soybean quality is highest at harvest, soybean producers should promptly dry newly harvested beans (Figure 15-1) to safe moisture levels in order to maintain their quality. In most cases, producers are able to adapt dryers that were designed for rice or corn for use with soybeans. However, dryers that recirculate or stir grain constantly should be avoided. Drying fans sized for rice or corn will produce greater airflow through soybeans, resulting in a higher drying rate. This chapter will discuss the principles and methods of on-farm drying for soybeans, fans, storage, grain handling safety and soybean drying costs.

Fundamentals of Soybean Drying

Drying Process

The ultimate goal of soybean drying is to get rid of the excess moisture in the kernel in order to make it less accessible to living microorganisms, such as fungi and bacteria. In this process, moisture is evaporated from the kernel to the surrounding air. Therefore, soybeans are dried in most cases by passing relatively large volumes of air, either ambient or heated, through the grain. Figure 15-2 shows an example of an on-farm grain drying and storage site. The quality of the drying air determines the final moisture content of the bean kernels. In addition, the



Figure 15-2. Grain drying and storage bins.

speed of soybean drying (known as the drying rate) depends on the moisture content and temperature of kernels as well as on the temperature, relative humidity and velocity of the drying air. Soybeans are typically dried down to 13.0% or 12.0%, depending on whether they are going to be marketed directly or stored for several months.

Air Properties

Air is the means by which grain is dried, serving as the medium that transports moisture away from the grain. Air contains some energy and humidity. Air quantity and quality are important factors that determine the final moisture content of kernels. Its quantity is the volume of air that the drying fan can deliver. More specifically, it should be divided by the number of bushels the drying air passes through, presented as cubic feet per minute per bushel (cfm/bu). On the other hand, air quality is related to its temperature and relative humidity. Air properties are determined graphically using a psychrometric chart (Figure 15-3).

It should be noted that a specific volume of air (say, 1 cubic foot) at a certain temperature has the capability to hold a specific amount of moisture. Increasing the temperature of that volume of air increases its capacity to carry more moisture, as shown in Figure 15-3. It is noticeable that air temperature at Tdb2 is greater than at Tdb1. As a result, air relative humidity (RH) at the higher temperature, RH2, is greater than that at the lower temperature,

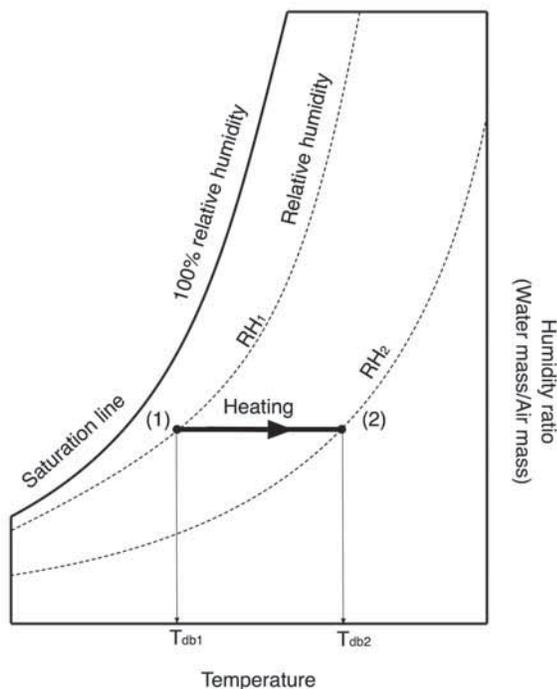


Figure 15-3. Psychrometric chart.

RH1. This means that the air-drying capabilities could be increased by adding energy to the drying air. As a rule, the drying time is reduced by passing larger volumes of air over soybeans or by increasing the air temperature, or both. However, it should be mentioned that soybeans are sensitive to temperature fluctuations and can be easily damaged by air that is too hot or too dry. Accordingly, the recommended minimum airflow rates for drying soybeans are shown in Table 15-1.

Table 15-1. Minimum airflow rates for drying soybeans.

Measured Moisture Content (%)	Minimum Airflow Rate (cfm/bu)
18% to 20%	3.0
15% to 18%	2.0
13% to 15%	1.0
11% to 13%	0.5

Equilibrium Moisture Content

As mentioned earlier, in order to dry soybeans, a large quantity of high-quality drying air is passed through the bean pile deposited in a drying bin. At a given air temperature and relative humidity, there is a corresponding grain moisture content that the seed will achieve and will not gain or lose water beyond. This moisture level is known as the equilibrium moisture content (EMC). Table 15-2 shows the EMC of soybeans at different values of air temperature and relative humidity. For example, if the air temperatures and relative humidity are 60°F and 70%, respectively, the beans will be dried to 13.7% moisture content, assuming the air is allowed to pass through the soybean pile under the same conditions for a sufficient time. Increasing air temperature to 80°F at the same RH level will decrease EMC to 13.2%.

Table 15-2. Soybean equilibrium moisture content.

Temperature (°F)	Relative Humidity (%)						
	30	40	50	60	70	80	90
40	6.4	7.7	9.3	11.3	14.2	18.9	28.7
50	6.3	7.6	9.1	11.1	14.0	18.6	28.2
60	6.2	7.4	8.9	10.9	13.7	18.3	27.8
70	6.1	7.3	8.8	10.7	13.5	17.9	27.3
80	5.9	7.1	8.6	10.5	13.2	17.6	26.9
90	5.8	7.0	8.4	10.3	13.0	17.3	26.5
100	5.7	6.9	8.3	10.1	12.7	17.0	26.1

Soybean Shrink Factor

Each soybean kernel contains dry matter and oil, which represent the grain's primary value, in addition to water. Most buyers use the moisture content (MC) of 13.0% as the base moisture for soybeans. When grain is delivered to the elevator above its base MC, buyers use a factor called "the shrink factor" in order to adjust the quantity for the excess moisture. This is because grain buyers will not pay for the cost of removing the excess water. Applying the shrink factor approximates the equivalent number of bushels that would be in the load if the grain was dried to the base MC. Conversely, some farmers often deliver grain to the elevator at moisture levels below the base MC. This case is also less profitable to the producer since the buyer will not apply an expansion factor. These factors clearly demonstrate how sensitive the soybean production economics are to the moisture content of the soybean kernels sold. A good example to demonstrate the potential loss due to soybean shrinkage using 200 tons of dry matter as basis for calculations is shown in Table 15-3. It is clear from column 6 that the penalty due to shrinkage increases with the increase in the soybean moisture. The buyer determines the penalty due to shrinkage as follows:

$$\text{Shrinkage penalty (bu)} = \text{total weight (bu)} \times 0.013 \times (\text{mc decimal} - 0.13)$$

It is clear that marketing soybeans at any moisture level greater than 13.0% will decrease the total profit.

The total removable water could be determined as follows:

$$\text{Total removable water (lb/bu)} = (52.2 / (1.0 - \text{mc decimal})) - 60.0$$

Table 15-3. Effects of shrinkage factor on total loss.

Dry Matter Content	Moisture Content	Excess Moisture	Soybean Gross Weight	Total Soybean Weight	Penalty Due to Shrinkage
lb	%	%	lb	bu	bu
200,000	13.0	0	229,885	3,831	0
200,000	14.0	1	232,558	3,876	50
200,000	15.0	2	235,294	3,922	102
200,000	16.0	3	238,095	3,968	155
200,000	17.0	4	240,964	4,016	209

Soybean Drying and Handling Guidelines

Soybean Harvesting

The preferable moisture content for soybeans at harvest is about 14%. With an adequate drying setup on the farm, producers could potentially harvest their grain at higher moisture contents, i.e., up to 18%. Drying soybeans to safe levels of moisture content requires removing significant amounts of water, which in turn increases the cost of drying. On the other hand, if soybeans were left to dry a little more in the field, a smaller range of moisture removal would be required for storage (usually less than 5%), making soybean drying relatively easier when compared to other grains. Therefore, producers can maximize their return by allowing the beans to dry in the field, down to approximately 14%-16% moisture content, before harvest if the weather conditions allow.

Air Relative Humidity

Prior to exploring available on-farm drying methods, it should be mentioned that the most unusual drying characteristic of soybeans is the susceptibility of the seedcoat to cracking and splitting. The key factor in avoiding seedcoat cracks is to keep the relative humidity of the drying air above 40%. When exposed to air below 40% relative humidity for extended periods, the seedcoat becomes very susceptible to cracking. As an example, assume that a producer uses air at 70°F and relative humidity of 70% for drying. If the air temperature increased to 90°F, the air relative humidity will drop to about 35% since air relative humidity is roughly cut in half with each 20°F increase in its temperature. As a result, this case will compromise the grain quality due to the decreased level of relative humidity. In other words,

although the temperature is not exceedingly high, the drop in relative humidity below 40% will cause some seedcoat cracking.

Air Temperature

The maximum safe temperature for the heated air used in drying soybeans is determined by the final use for those beans. As mentioned earlier, high drying temperatures can easily cause widespread seedcoat cracks and splits. If soybeans are intended for both oil production and food production, the temperatures in heated-air batch driers should be limited to 130°F. On the other hand, the soybeans that are used for seed should not be exposed to air above 100°F. However, even at this relatively mild temperature, seedcoat cracks are likely to occur. Therefore, temperatures below 85°F might be the safest recommendation.

Soybean Handling

Soybean seeds, like corn or rough rice, are susceptible to mechanical damage. The mechanical damage to the soybean seed results from the impact with a hard surface or the impact with other seeds. The extent and severity of mechanical damage depends on the seed moisture content, velocity at impact and the hardness of the impacted surface. Unfortunately, a certain amount of splitting will occur each time they are dropped. For example, a single 10-foot drop of soybean seeds, at less than 12% moisture, against a metal surface can reduce germination by 10% to 15%. Therefore, handling of soybeans should be minimized and if necessary performed as gently as possible.

On-Farm Drying Methods

As mentioned earlier, there are different factors that should be taken into account while drying soybeans. Therefore, drying systems that were designed for other grain can be used to dry soybeans but only after careful selection of the appropriate air temperature and relative humidity levels. Drying systems that facilitate extreme high temperatures for air-drying (130°F-150°F) should be avoided when drying soybeans to minimize seedcoat cracks. Batch and continuous-flow drying systems are less desirable in drying soybeans because the heat input is difficult to reduce, not to mention they require more handling than is required for in-bin drying systems. Consequently, bin-drying systems, i.e., natural-air drying and low-temperature drying, are usually the best options for drying soybeans.

Natural-Air Drying

Natural-air drying is a technique used to dry soybeans by passing unheated (natural) air through the soybean mass until its moisture content reaches the EMC level. Since soybeans are hygroscopic (susceptible to moisture absorption), their moisture content will adjust according to the quality of air used. Therefore, drying soybeans with natural air can be accomplished only if the air temperature and relative humidity conditions allow a net moisture transfer from the soybeans to the air. The drying speed under natural-air drying depends on the moisture content of the soybeans as well as the temperature and relative humidity of the drying air. Natural-air bin drying systems are very efficient for drying soybeans but can only be used under favorable weather conditions. As a rule, air temperature should be above 60°F and the humidity below 75% to achieve natural-air drying.

A natural-air drying system (Figure 15-4) typically consists of a bin with a perforated floor equipped with a drying fan, a grain spreader, a sweep auger and an unloading auger. Stirring devices may also be added. An external energy source, typically from fossil fuels, is required to supply the electricity for the drying fan and the various augers. On the other hand, the energy required for evaporating the moisture from the soybeans comes from the energy already present in the ambient air. Successful soybean drying with natural air is usually the most energy-efficient method of drying. However, it is also the slowest drying method and has the greatest potential for grain spoilage. Furthermore, natural-air drying is extremely sensitive to weather conditions. Consequently, it requires the highest level of management if spoilage problems are to be prevented. Special attention should be paid to soybean management

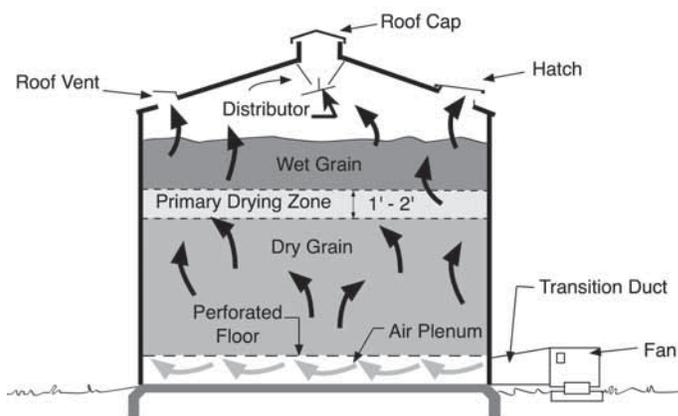


Figure 15-4. Natural-air drying bin.

practices in natural air when excessive moisture or adverse weather is encountered. Unheated air-drying will not be feasible in extended periods of damp weather.

Low-Temperature Drying

In low-temperature drying of soybeans, the drying air is heated 10°F above ambient conditions. Similar to natural-air drying, low-temperature drying also requires a perforated-floor bin, a grain spreader, under-floor unloading auger and a sweep auger. A stirring device may also be added. The low-temperature drying technique has a higher potential to dry soybeans to the accepted long-term storage moisture contents when compared to natural-air drying. Soybeans could be dried using the low-temperature drying technique then 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. Thus, successful low-temperature drying is relatively economical in terms of energy cost when compared to higher-temperature techniques. Attention should be paid also to the fact that more energy is required to operate the drying fans than is needed to heat the air.

Soybean producers could use their corn dryers under specific environments. They should set the drying air temperature lower than they use for corn and they also should avoid dryers that recirculate the crop during drying. This is because the soybeans are susceptible to fracture if they are dried too fast or handled roughly. Some researchers reported that it might be possible to use the corn dryer for soybean drying. Producers should limit drying air temperature to 130°F-140°F for commercial beans and 100°F for seed beans. Retention time in the heated section of dryers should be less than 30 minutes. They also recommended that the relative humidity of the drying air should be greater than 40% to help prevent skin cracks. Studies have shown that it is possible to develop 50%-100% splits in less than 5 minutes of exposure time if incorrect drying procedures are followed. Cracked soybeans will not keep well in storage and will break easily during handling. Therefore, in some cases, it is recommended to use a simple shield to recirculate some of the moist drying air back to increase the humidity of the drying air. This approach facilitates a safe and gradual increase in drying temperatures. Alternatively, filling the bin halfway will double the drying air volume per bushel of grain, thus decreasing the time needed to accomplish the desired drying levels.

Grain-Drying Fans

Grain bin fans are responsible for circulating air through the grain for holding, drying and cooling processes. Fans also determine the rate of air circulation. Once again, air is the most essential element to successful grain operations since it controls grain moisture and temperature, reduces biological and insect activity and prevents moisture migration. It is desirable during grain drying to move as much air through the grain as possible. Technically, doubling the airflow reduces the drying time by about 50%. Practically, however, all fans are susceptible to a drop in the capacity of air that can be circulated as the static pressure increases. Therefore, careful selection of grain fans is a necessity to ensure fast and efficient drying.

Types of Grain-Drying Fans

There are two basic types of fans, i.e., the axial flow fan and the centrifugal fan. The axial flow fan (Figure 15-5) closely resembles a ceiling fan. Centrifugal fans (Figure 15-6) are encased in a round housing that rotates and forces air to move in a direction perpendicular to that of air entry.

Axial fans supply more cubic feet per minute (cfm) per unit of horsepower at low grain depths (static pressures below 4.5 inches of water) when compared to centrifugal fans. That is why axial fans



Figure 15-5. Axial flow fan.



Figure 15-6. Centrifugal fan.

are preferable in shallow-depth bin-drying systems such as batch-in-bin and continuous-in-bin systems. Axial fans are also suitable for deep-bin drying (up to 20-foot depth) when a flow of 1 cfm/bushel or less is required. They are generally lower in initial cost but operate at a higher noise level than centrifugal fans. These fans are typically unsuited for use in bins that will also handle rice due to the high static pressures expected – typically, air is more difficult to move up through a column of rice. Axial flow fans are less costly than centrifugal fans. In cases where a high static pressure is expected, centrifugal fans are usually selected.

Centrifugal fans supply more cfm per horsepower at static pressures above 4.5 inches of water when compared to axial fans (Figure 15-4). These are especially suited for deep grain beds (12 to 20 feet) where high volumes of air circulation are required. In addition, centrifugal fans are selected when low operation noise is a factor. Larger diameter centrifugal fans typically move more air per horsepower.

Fan Performance

Fan performance is normally illustrated in a graph (performance curve) or a performance table showing the correlations between airflow rate (cfm), static pressure (inches of water) and the horsepower. Each fan type has its unique performance characteristics, similar to the curves presented in the

graph below (Figure 15-7). The static pressure of a drying bin is a measure of the resistance of the grain bed to airflow. In a properly designed system, grain is the main restrictor to airflow within the bin. The selected fan must operate at the static pressure needed to overcome this airflow resistance. From the graph below it is clear that using a centrifugal fan is recommend in most cases, particularly with medium to high static pressure. This is because as the depth of the grain increases, the value of static pressure required for moving air through the grain increases. Additionally, centrifugal fans are less noisy than axial fans if both were pushing the same volumes of air. It should be noted that the curves shown here are presented as examples and should not be used in system planning.

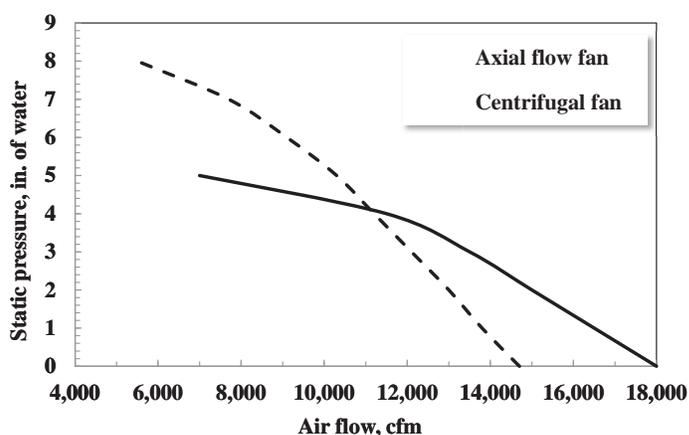


Figure 15-7. Axial and centrifugal fan curves.

As mentioned earlier, the static pressure increases with the increase in grain depth. Therefore, the critical question is what is the acceptable number of soybean bushels that a producer can place in a bin during the drying process? The following steps are useful to answering this question:

1. Determine the soybeans' moisture level.
2. Look at Table 15-1 to determine the minimum cfm per bushel that is needed at that moisture level.
3. Go to the fan chart or table and determine the cfm corresponding to each static pressure level.
4. Measure static pressure with a manometer.
5. Determine the amount of air being moved, cfm, by the fan.
6. Determine the number of soybean bushels in the bin.
7. Limit the fill level to keep the cfm per bushel within acceptable limits.

Drying Fan Selection

Airflow rates for drying vary from 0.5 cfm/bu to more than 50 cfm/bu for commercial or batch dryers. For on-farm drying, airflow rates vary from 0.5 to 6 cfm/bu, depending on the initial moisture content of the grain and on the amount of heat added to the drying air. Several rules of thumb have been developed for sizing fans in drying systems: (1) doubling the grain depth at the same airflow rate (cfm/bu) requires 10 times the horsepower, and (2) doubling the airflow rate (cfm/bu) on the same depth of grain requires 5 times the horsepower. These rules can be seen clearly from Figure 15-8. The available power can be quickly overwhelmed as the grain depth and/or air requirements (cfm) increase.

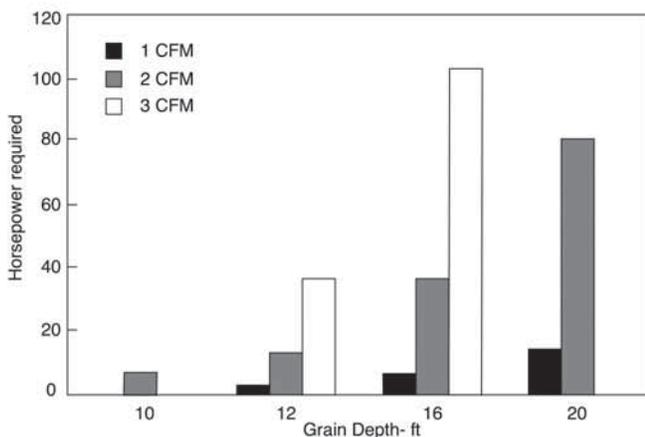


Figure 15-8. Fan power requirements versus depth.

Fundamentals of On-Farm Soybean Storage

Newly harvested soybeans are at their highest quality when they come from the field to the drying and storage facilities. Producers are looking to follow all the required instructions that help preserve that quality. Dried soybeans may be easily stored in facilities that were designed for rice or wheat. Air moves through relatively clean soybeans, more than many other grain types. As mentioned earlier, beans should be dried as quickly as possible to moisture levels of 13% or less without inducing thermal cracks in the seedcoat. A moisture level of 11% is desirable if beans are to be kept longer than six months. Beans should also be cooled to avoid moisture collection throughout the winter season. Dry and cool beans are relatively safe from fungi and insects – the two primary potential sources for grain damage.

Table 15-4. Safe Soybean Storage Periods (Number of Days).

Moisture Content (%)	Soybean Temperature (°F)					
	30	40	50	60	70	80
11	>300	>300	>300	>300	200	140
12	>300	>300	>300	240	125	70
13	>300	>300	230	120	70	40
14	>300	280	130	75	45	20
15	>300	200	90	50	30	15
16	>300	140	70	35	20	10
17	>300	90	50	25	14	7

The length of the storage period influences the amount of spoilage in grain. In general, the longer the storage period, the lower the moisture content should be to ensure safe storage. Microbial growth and reproduction can occur even under conditions considered safe for storage, although the growth would be difficult to detect. This effect could eventually become detectable after very long storage time.

- Allowable storage time is the storage period before quality loss is expected to affect the grain.
- Airflow through the grain maintains the grain temperature but does not extend the allowable storage time beyond that listed in Table 15-4.
- Allowable storage time is cumulative. If 16% moisture soybeans were stored for 35 days at 50°F, one-half of the storage life has been used. If these soybeans were cooled to 40°F, the allowable storage time at 40°F is only 70 days.

Storing soybean seed at moisture contents that are too high often results in rotting or decreased germination within just a few days. When compared to corn, soybeans are more susceptible to spoilage due to their higher moisture content. Consequently, soybeans need to be about two points drier than corn for the same storage period. Researchers at Iowa State University established the following moisture levels, which correspond to different storage periods:

1. 13% or less for commercial storage during winter storage.
2. 12% or less for up to one year.
3. 11% or less for more than one year.

4. 12% or less for soybean seed stored for one planting season.
5. 10% or less for carryover seed.

Soybean moisture level is critical for maintaining storage quality. Beans should be kept at moisture levels of about 12% or less. Access to an accurate moisture meter is highly recommended for bean storage. Moisture levels may also affect germination quality. Moisture-related problems will usually change the appearance of the kernel. However, the viability or germination of soybeans will often decline before there is any visual change in the appearance – and almost certainly if there are obvious appearance changes. Storage temperature plays an important role with moisture interaction. Warmer temperatures require drier beans in order to maintain the same quality. Seed beans should be kept at lower moisture levels. Moisture levels of 10% are recommended for long-term storage in the southern regions of Arkansas, with a maximum of 12% in the northern parts.

Aeration

Even after drying soybeans down to an acceptable moisture level, care must be taken to maintain the beans at this level. Soybeans have the ability to lose and regain moisture more readily than many other grains. This explains why moisture migration and condensation seem to occur faster in soybeans. Moisture will be drawn in from outside the bin, and natural convection currents will set up – resulting in an accumulation of moisture in the center and top area of the grain. If the center area is allowed to stay moist for any length of time, it is an excellent area for fungi growth if temperatures become favorable.

Aerate with natural air once the grain is below 13%. The grain should be cooled as much as possible with early fall conditions. Cooling air should be checked for humidity, being careful to aerate when humidity is below about 60%, or better yet when the EMC content is at or below the grain target moisture level. Aeration with high-humidity air will add moisture back to the grain. Accumulated moisture can typically be managed very easily if the grain is aerated every couple of weeks. As the grain temperature in the bin stabilizes, all the beans get about the same temperature; the moisture migration problem will lessen.

Probe the bin periodically to check for insect infestation and grain temperature increase. Grain temperature increase usually means moisture migration. Aerate whenever this is detected. If the problem is in the center of the bin and aeration is not effective, moving the grain to another bin to solve the problem may be necessary. Problems in the center of the bin usually indicate a lot of fines and/or trash accumulated in this area during filling.

Temperature

Fall Aerate continuously at any time when the equilibrium moisture content is acceptable and air temperature is 10°F to 15°F cooler than grain temperature until grain is cooled to 40°F.

Winter Aerate about every two weeks when air temperature is within 10°F of grain temperature. Try to get at least 24 hours of drying time per two-week period.

Spring When mean daily temperatures show steady increase, aerate continuously whenever air temperature is 10°F to 15°F warmer than grain temperature until grain temperature reaches 60°F to 65°F.

The key to excellent on-farm soybean storage is controlling the moisture level in soybeans. This requires excellent management coupled with an adequate aeration system.

Fungi and Insects

Fungi and insects are both fueled by high moisture levels and are more apt to occur in trashy grain or in grain with many damaged kernels. High temperatures and high humidity set up an excellent scenario for fungi to grow. Once grain is cooled down to 40°F, the likelihood of fungi growth is much less. Fungi are the most important cause of soybean damage in storage. Soybeans have an excellent seed-coat, which helps protect them from insect assault. Insects are more likely to attack damaged beans – either from handling damage or being damaged by some other source, such as fungi.

Soybean Storage Tips

- Cool the grain off as soon as possible in the fall. Target temperatures should be initially around 60°F.
- Continue to aerate and uniformly cool grain to between 30°F to 40°F if possible. This will help avoid internal moisture migration and insect activity.
- Monitor grain and aerate monthly to maintain uniform temperature and moisture levels throughout. Aerate more often if moisture or temperatures increase.
- Keep the grain cool as long as possible into the early spring.
- Do not aerate in early summer unless problems develop.
- Cover fans and openings when not in use to help avoid air, moisture and potential insect movement.
- Monitor carefully and fumigate if needed.
- Inspect soybean surface at least every week throughout the storage period.

Soybean Handling Safety

Soybean producers should always think safety first around drying and storage bins because grain suffocation accidents happen all too often. Wear an effective dust mask when exposed to grain dust when working in dusty conditions, particularly those resulting from moldy or spoiled grain. Exposure and inhalation of mold can cause severe allergic reactions.

Good safety practices are necessary for producers and workers who operate in soybean drying, storage and handling. Grain drying and handling can be dangerous. A deadly hazard exists for anyone in a grain bin as deaths occur every year from suffocation and injuries caused by unloading augers. Power to the unloading auger should be disconnected before entering bins. A knotted safety rope hanging near the center of the bin offers greater protection, and a second person should be standing by who can offer

assistance. Air pockets sometimes form when grain bridges over unloading augers due to spoiled grain and moisture. This crusted surface should not be walked over because the pocket can collapse. Transport augers can hit power lines, unguarded augers can catch hands or feet, and fans and shafts can catch unsuspecting victims.

Soybean Drying Costs

Maintaining the drying cost in the minimum level is important in order to maximize profits (returns on investment). As mentioned earlier, in order to dry soybeans, producers need to determine the total pounds of water they will remove from 1 bushel of grain. The number of BTUs to extract 1 pound of water will vary from 1,100 to 1,400, depending on how easily moisture is given up by the kernel. As the kernel begins to dry, more energy is needed to extract the last bit of moisture. A good estimate is to use an average of 1,200 BTU/pound of water to calculate the energy needed to get rid of 1 pound of moisture. Table 15-5 summarizes the BTU/unit of fuel as well as the burning efficiency.

Table 15-5. Heating value of fuels as well as their corresponding efficiencies

Fuel	BTU	Unit	Burning Efficiency
LP gas	92000	gallon	80%
Natural gas	1000	ft ³	80%
Electricity	3413	kWh	100%

Drying costs may be estimated using the following equations:

Fan motor cost:

$$\text{Fan motor cost (\$/h)} = \text{fan HP} \times 0.7475 \text{ (kW/HP)} \\ \times \text{electricity cost (\$/kW.h)}$$

Fuel cost:

$$\text{Fuel cost (\$/bu)} = \left[\frac{(\text{BTU/lb}_{\text{water}}) \times (\text{lb}_{\text{water removed}}/\text{bu})}{(\text{BTU/unit of fuel})} \right] \\ \times \text{fuel cost (\$/unit of fuel)} \times 100 \\ \times \text{burning efficiency \%}$$

Example 1

Assume that you have a 20 HP fan with an electricity cost at \$0.10 kWh, no demand charges are applied; determine the cost to run this fan per hour of operation:

$$\text{Fan motor cost (\$/h)} = 20 \text{ HP} \times 0.7475 \text{ (kW/HP)} \\ \times 0.10 \text{ (\$/kW.h)} = \$1.50$$

Example 2

Determine the drying cost per bushel of soybeans harvested at 20% to 13% moisture using LP at a cost of \$2.40/gallon.

There are 5.25 pounds of water per bushel above the value for 13% soybeans to be removed. Following, the fuel cost could be determined using the equation below:

$$\text{Fuel cost (\$/bu)} = \\ \frac{[1200 \text{ (BTU/lb)}_{\text{water}} \times 5.25 \text{ (lb)}_{\text{water removed}}/\text{bu}] \\ \times 2.40 \text{ (\$/unit of fuel)} \times 100}{[92,000 \text{ (BTU/unit of fuel)} \times 80\%]} = \$0.205$$

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