Natural Air/Low Temperature Grain Drying

Cooperative Extension South Dakota State University
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LOW TEMPERATURE
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South Dakota State University
U.S. Department of Agriculture
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Jerry Lush
Extension agricultural engineer

Natural air drying is the most energy efficient way to dry grain. It is a slow process and uses the ability of air to evaporate moisture from grain kernels.

Low temperature drying uses the same principles as natural air drying except that from 2 to 10 degrees of heat are added to the air to permit drying in a shorter time.

Natural air and low temperature drying require 4 to 8 weeks drying time and initial grain moisture contents of 26% or less.

A high quality grain is obtained because kernel seed coats do not develop stress cracks or break. Grain is also stored in the same bin in which it is dried, reducing mechanical damage from repeated handling.

Natural air and low temperature drying reduce the need for petroleum based fuels, but will increase electricity demand on the farm.

Drying bin
The drying bin (Fig 1) should have a fully perforated drying floor, so that drying air moves evenly throughout the grain.

Provide a fan able to deliver at least one cubic foot of air per minute per bushel of grain (cfm/bu) when the bin is full. Figure size of exhaust vents in the top of the bin at one square foot per 1000 cfm of fan capacity.

A distributor is recommended to spread fine materials evenly throughout the bin while filling. Screen grain before putting it in the bin to remove as many fines as possible. Fines will fill air spaces between grain kernels, blocking air movement through portions of the bin.

Uniform airflow is essential. If grain is put into a bin without using a distributor, fines accumulate under the spout. The resulting cone of fines will let little—if any—air through. This portion of the grain in the bin will remain wet and spoil readily.

Level grain in the bin to get uniform airflow rates throughout the bin. Airflow will be less through the peak of a grain pile than through the sides.

An electric resistance heater is normally used to add supplemental heat for low temperature drying. Heat from a solar collector can also be used.

Drying takes place in a drying zone (Fig 2). This zone is 1 to 2 feet deep and advances through the grain as drying progresses.

Grain above the drying zone will remain near its original moisture content until the drying zone reaches it. Grain temperature will be lower than outside air because of evaporation taking place in the drying front. Moisture content of dried grain below the drying zone will be determined by the drying air temperature and relative humidity.

Equilibrium moisture content
Grain will reach a certain moisture content if air, containing a constant relative humidity and
temperature, is continually passed through it. This is called the “equilibrium moisture content.”

Table 1 shows the equilibrium moisture content of corn for various air conditions. Air at 50°F and 70% relative humidity will dry grain to 15.1% moisture. Add heat to the drying air to increase temperature and lower relative humidity. This increases the drying capacity of the air. A 5° rise will reduce relative humidity about 10%.

Table 1. Equilibrium moisture content of shelled corn.

<table>
<thead>
<tr>
<th>Relative humidity</th>
<th>Air T°F</th>
<th>50%</th>
<th>60%</th>
<th>70%</th>
<th>80%</th>
<th>90%</th>
</tr>
</thead>
<tbody>
<tr>
<td>30</td>
<td></td>
<td>13.1</td>
<td>14.8</td>
<td>16.6</td>
<td>18.7</td>
<td>21.5</td>
</tr>
<tr>
<td>35</td>
<td></td>
<td>12.7</td>
<td>14.4</td>
<td>16.1</td>
<td>18.2</td>
<td>21.0</td>
</tr>
<tr>
<td>40</td>
<td></td>
<td>12.4</td>
<td>14.0</td>
<td>15.8</td>
<td>17.8</td>
<td>20.6</td>
</tr>
<tr>
<td>45</td>
<td></td>
<td>12.1</td>
<td>13.7</td>
<td>15.4</td>
<td>17.4</td>
<td>20.1</td>
</tr>
<tr>
<td>50</td>
<td></td>
<td>11.9</td>
<td>13.4</td>
<td>15.1</td>
<td>17.0</td>
<td>19.7</td>
</tr>
<tr>
<td>55</td>
<td></td>
<td>11.6</td>
<td>13.1</td>
<td>14.8</td>
<td>16.7</td>
<td>19.3</td>
</tr>
<tr>
<td>60</td>
<td></td>
<td>11.4</td>
<td>12.9</td>
<td>14.5</td>
<td>16.4</td>
<td>19.0</td>
</tr>
</tbody>
</table>

Calculated from Thompson, T.L., ASAE Transactions 15 (2): 333-337.

Air at 30°F and 80% relative humidity will dry grain to 18.7% moisture. If 5°F heat is added, temperature will raise to 35°F and the relative humidity will drop to about 70%. Air at these new conditions will dry grain to around 16% moisture.

Air will pick up some heat, about 2 degrees, just by passing over the fan motor.

Use 24-hour average air temperature and relative humidity to determine equilibrium moisture content.

Dry grain below the drying zone acts as a buffer for air temperatures and relative humidity. Some heat from the daytime hours will be stored in the dry grain. Colder, more humid night air will be warmed up as it moves through the grain.

Dry grain may rewet slightly during periods of high relative humidity, though only to about 1 percentage point below the “equilibrium moisture content.” Drying will continue in the drying front since moisture was removed from the air by the dry grain.

Keep the drying front moving through the grain. This is critical to successful natural air and low temperature drying. The drying front must reach the top of the bin before that grain spoils.

Airflow rate will have more effect on the movement rate of the drying front than adding heat. As airflow rate increases, more air per unit of time moves through the grain, and more moisture is removed. The equilibrium moisture content remains the same.

Adding heat will allow air to hold more moisture, but some of this moisture will come from the “dry” grain since the equilibrium moisture content has now changed. Depending on the conditions, the bottom grain may be overdried.

**Allowable storage time**

Grain can be stored a certain length of time before developing enough mold to drop one market grade. This is known as “allowable storage time” and is determined by the grain moisture content and temperature relationship. Allowable storage times for corn are given in Table 2. Allowable storage times for other grains have not been developed.

Table 2. Allowable storage time in days for shelled corn.

<table>
<thead>
<tr>
<th>Corn Moisture content</th>
<th>T°F</th>
<th>14</th>
<th>15</th>
<th>16</th>
<th>17</th>
<th>18</th>
<th>22</th>
<th>24</th>
<th>26</th>
<th>28</th>
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<tr>
<td>30</td>
<td>847</td>
<td>503</td>
<td>323</td>
<td>160</td>
<td>95</td>
<td>64</td>
<td>47</td>
<td>37</td>
<td>31</td>
<td></td>
<td></td>
</tr>
<tr>
<td>35</td>
<td>634</td>
<td>377</td>
<td>242</td>
<td>120</td>
<td>71</td>
<td>48</td>
<td>35</td>
<td>28</td>
<td>23</td>
<td></td>
<td></td>
</tr>
<tr>
<td>40</td>
<td>474</td>
<td>282</td>
<td>181</td>
<td>90</td>
<td>53</td>
<td>36</td>
<td>26</td>
<td>21</td>
<td>17</td>
<td></td>
<td></td>
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<tr>
<td>45</td>
<td>365</td>
<td>211</td>
<td>135</td>
<td>67</td>
<td>40</td>
<td>27</td>
<td>20</td>
<td>15</td>
<td>13</td>
<td></td>
<td></td>
</tr>
<tr>
<td>50</td>
<td>266</td>
<td>158</td>
<td>101</td>
<td>50</td>
<td>30</td>
<td>20</td>
<td>15</td>
<td>12</td>
<td>10</td>
<td></td>
<td></td>
</tr>
<tr>
<td>55</td>
<td>199</td>
<td>118</td>
<td>76</td>
<td>38</td>
<td>22</td>
<td>15</td>
<td>11</td>
<td>9</td>
<td>7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>60</td>
<td>149</td>
<td>88</td>
<td>57</td>
<td>28</td>
<td>17</td>
<td>11</td>
<td>8</td>
<td>6</td>
<td>5</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Calculated from research completed at USDA Grain Storage Research Laboratory, Ames, Iowa. Based on 0.5% dry matter loss from kernels with normal harvest damage; kernels with greater damage will spoil two to five times faster.

Use Table 2 only as an estimate of the safe storage period, since many other things (mechanical damage, corn variety, and growing conditions, for example), will affect storage time.

Lowering grain temperature will increase allowable storage time, as will lowering moisture content. Lowering the grain temperature by 10°F will almost double allowable storage time.

The proportion of time spent at a set of temperature and moisture content conditions will reduce table values for a new set of conditions by a similar proportion.

For example, if 26% moisture corn is held at 60°F for 2 days, 2/8 or 25% of the allowable storage time is already used up. If the corn temperature is then lowered to 45°F, the number of days at that set of conditions, 20 days, would be lowered by 25% to 15 days. After five days at these conditions, 50% of the allowable storage time has been used.
Do not harvest grain for low temperature drying when the moisture content is too high or when the average temperatures are too high. The allowable storage time for such grain is not sufficient for low temperature or natural air drying. Consider this also when determining the amount of additional heat for low temperature drying.

**Management**

Use the "allowable storage time" table as a basis for management and operating natural air and low temperature drying. Delay harvest for low temperature and natural air drying until the average 24-hour temperature is near 50°F. Do not use supplemental heat when the air temperature is 50°F or above. These recommendations will keep the grain temperature down, allowing time for drying the grain.

The minimum airflow rates shown in Table 3 are recommended for the corresponding grain moisture contents for low temperature and natural air drying. These airflow rates will normally insure that the grain will dry before spoiling. Farmers in southeastern South Dakota should lower the moisture content by one percentage point to compensate for warmer temperatures and higher humidity compared to other areas of the state.

**Table 3. Minimum airflow rates for low temperature and natural air corn drying.**

<table>
<thead>
<tr>
<th>Airflow rate</th>
<th>Initial moisture content</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Low temperature</td>
</tr>
<tr>
<td>1 cfm/bu</td>
<td>22%</td>
</tr>
<tr>
<td>2</td>
<td>24%</td>
</tr>
<tr>
<td>3</td>
<td>26%</td>
</tr>
</tbody>
</table>

Turn on the drying fan as soon as the entire bin floor is covered with grain. Operate the fan continuously even during rainy or foggy weather, until one of the following conditions occurs:

1. The drying front has moved through the grain and the top of the grain is at the desired final moisture content, or
2. The grain at the top of the bin is 18% moisture content or less and temperature of this grain has dropped to about 30°F.

Condition two may occur in some years with natural air drying. This grain can be kept through the winter and drying can be completed in the spring. Start spring drying when the 24-hour average temperature reaches about 40°F.

Check grain weekly during the winter and aerate as needed to control temperature and moisture migration (see FS 774, Aeration of grain in storage). Aeration practices also need to be followed for dry grain in storage.

Grain dried with supplemental heat can reach the desired final moisture content in the fall. Various heating schedules can be followed.

Add heat continuously throughout the drying period even though some overdrying of bottom grain will occur. Overdrying decreases if the addition of heat is delayed. The energy requirement for heat will also be reduced as more drying is done with natural air. You might wait to add heat until the average 24-hour temperature drops to 40°F or even down to 30°F.

Stirring devices can be used with low temperature or natural air drying systems to mix the higher moisture top grain with the drier bottom grain.

Stirring will loosen grain in a bin and increase airflow rate; however, overstirring will cause fines to settle to the bottom of the bin. This can reduce airflow. Stir grain thoroughly once a week. If a stirrator is shut off in a full bin, problems may be encountered when trying to restart it.

Follow recommended moisture contents and airflow rates for low temperature drying even when a stirrator is used. Weigh the energy costs for operating a stirrator against the cost of overdrying the bottom grain encountered without it.

A properly designed and managed low temperature or natural air system will not require stirring. Stirring lowers drying efficiency by eliminating the drying front.

You can use natural air or low temperature drying on grain harvested at high moisture content by layer filling or combination drying.

Using this technique you can dry grain as high as 26% moisture even if the full bin capacity of the fan is 1 cfm/bu. A bin partially filled will allow the fan to provide a higher airflow due to a lower static pressure than for a full bin. Since the layer has fewer bushels than a full bin, the cfm/bu will be larger.

If a fan will supply 1 cfm/bu for a full bin, a layer of grain a third of a bin deep will allow at least 3 cfm/bu of airflow. When one layer is dry another can be added.

Combination drying consists of partially drying the grain with a high temperature dryer, then finishing with low temperature or natural air drying. This method insures the proper moisture content for the second drying system. It takes much less energy and time for a high temperature dryer to reduce moisture to 22% than to dry to 15½%.
About one percent of the moisture is removed simply by removing hot grain from the high temperature dryer and cooling it in the drying bin. That means, if 22% moisture corn is your goal, you only need to dry corn to 23%, then transfer it to the drying bin.

Recommendations
Natural air and low temperature drying systems are energy efficient but have to be managed properly to keep the grain from spoiling. The following recommendations should insure a successful drying season:

- Equip drying bin with a fully perforated floor.
- Provide a fan with at least 1 cfm/bu at full bin capacity.
- Screen grain and use a distributor.
- Level grain.
- Harvest at proper moisture contents for available airflow rates.
- Start fan when floor is covered and operate continuously.
- Use layer fill or combination drying if conditions warrant.
- Do not add heat if the air temperature is 50° or above.

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