Grain Storage
Best Management Practices

Michigan Webinar
March 31, 2020

Kenneth Hellevang, Ph.D., P.E.
Extension Engineer & Professor
Agricultural & Biosystems Engineering

EXTENDING KNOWLEDGE ➤ CHANGING LIVES

NDSU EXTENSION
Manage - to direct with a degree of skill

Monitor:
• Temperature
• Moisture
• Insects
• Mold
• Carbon dioxide

Check Grain Frequently
• 2-weeks until cooled
• 2-3 weeks during winter
• 2-weeks spring & summer

Manage: Aerate & Dry
• Temperature
• Moisture
Senses only grain near cable

- Cable
- Temperature sensor
- Temperature indicator
- Fan
Sensors & Fan Controllers

- StorMax Digital Monitor
  - One plug-in per bin/bin-group
  - Displays 32 sensors per screen
  - Graphical display
  - Stores 1+ years of historic data
  - Reads other kinds of cables
  - Easy upgrades for future technology
  - Optional PC upload

Technology does not replace Management!
# Recommended Long-Term Storage Moisture Content

<table>
<thead>
<tr>
<th>Grain</th>
<th>EMC @ 70°F, 60% RH</th>
<th>Moisture</th>
</tr>
</thead>
<tbody>
<tr>
<td>Barley</td>
<td>11.8%</td>
<td>12%</td>
</tr>
<tr>
<td>Canola</td>
<td>8.0%</td>
<td>8%</td>
</tr>
<tr>
<td>Corn</td>
<td>12.8%</td>
<td>13%</td>
</tr>
<tr>
<td>Flaxseed</td>
<td>8.3%</td>
<td>8%</td>
</tr>
<tr>
<td>Soybeans</td>
<td>10.2%</td>
<td>11%</td>
</tr>
<tr>
<td>Sunflower</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Non-Oil</td>
<td>9.6%</td>
<td>10%</td>
</tr>
<tr>
<td>Oil</td>
<td>7.4%</td>
<td>7-8%</td>
</tr>
<tr>
<td>Wheat</td>
<td>13.3%</td>
<td>13.5%</td>
</tr>
</tbody>
</table>

Mold Growth > 70% RH

EMC = 13.3%
### “Approximate” Allowable Storage Time for Cereal Grains (Days)

**Cumulative**

* Exceeds 300 days

<table>
<thead>
<tr>
<th>Moisture Content (%)</th>
<th>30°</th>
<th>40°</th>
<th>50°</th>
<th>60°</th>
<th>70°</th>
<th>80°</th>
</tr>
</thead>
<tbody>
<tr>
<td>14</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>200</td>
<td>140</td>
</tr>
<tr>
<td>15</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>240</td>
<td>125</td>
<td>70</td>
</tr>
<tr>
<td>16</td>
<td>*</td>
<td>*</td>
<td>230</td>
<td>120</td>
<td>70</td>
<td>40</td>
</tr>
<tr>
<td>17</td>
<td>*</td>
<td>280</td>
<td>130</td>
<td>75</td>
<td>45</td>
<td>20</td>
</tr>
<tr>
<td>18</td>
<td>*</td>
<td>200</td>
<td>90</td>
<td>50</td>
<td>30</td>
<td>15</td>
</tr>
<tr>
<td>19</td>
<td>*</td>
<td>140</td>
<td>70</td>
<td>35</td>
<td>20</td>
<td>10</td>
</tr>
<tr>
<td>20</td>
<td>*</td>
<td>90</td>
<td>50</td>
<td>25</td>
<td>14</td>
<td>7</td>
</tr>
<tr>
<td>22</td>
<td>190</td>
<td>60</td>
<td>30</td>
<td>15</td>
<td>8</td>
<td>3</td>
</tr>
<tr>
<td>24</td>
<td>130</td>
<td>40</td>
<td>15</td>
<td>10</td>
<td>6</td>
<td>2</td>
</tr>
<tr>
<td>26</td>
<td>90</td>
<td>35</td>
<td>12</td>
<td>8</td>
<td>5</td>
<td>2</td>
</tr>
<tr>
<td>28</td>
<td>70</td>
<td>30</td>
<td>10</td>
<td>7</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>30</td>
<td>60</td>
<td>25</td>
<td>5</td>
<td>5</td>
<td>3</td>
<td>1</td>
</tr>
</tbody>
</table>
"Approximate" Allowable Storage Time for Soybeans

<table>
<thead>
<tr>
<th>Moisture Content (%)</th>
<th>--- Grain Temperature (°F) ---</th>
<th>Approximate Allowable Storage Time (Days)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>30°</td>
<td>40°</td>
</tr>
<tr>
<td>11</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>12</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>13</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>14</td>
<td>*</td>
<td>280</td>
</tr>
<tr>
<td>15</td>
<td>*</td>
<td>200</td>
</tr>
<tr>
<td>16</td>
<td>*</td>
<td>140</td>
</tr>
<tr>
<td>17</td>
<td>*</td>
<td>90</td>
</tr>
<tr>
<td>19</td>
<td>190</td>
<td>60</td>
</tr>
<tr>
<td>21</td>
<td>130</td>
<td>40</td>
</tr>
<tr>
<td>23</td>
<td>90</td>
<td>35</td>
</tr>
<tr>
<td>25</td>
<td>70</td>
<td>30</td>
</tr>
<tr>
<td>27</td>
<td>60</td>
<td>25</td>
</tr>
</tbody>
</table>

* Exceeds 300 days

* Allowable storage time exceeds 300 days
Storability

- Cracked, broken, immature grain spoils easier
- Test weight is an indicator of storability
- Variety variation
Moisture Measurement

- Adjust for temperature
  - May not be accurate <40°F
- More sensitive to outside of kernel
  - Moisture variation after drying
  - Meters affected by condensation
- Growing season; foreign material effects

Recommend:
- Place sample in sealed container
- Warm to ~70°F
- Equilibrate moisture for 6-8 hours.
- Check moisture
- Compare to elevator or standard
Natural Air Drying
### Natural Air & Low Temperature Corn Drying Spring Drying

<table>
<thead>
<tr>
<th>Month &amp; added heat</th>
<th>Ave. Temp (°F)</th>
<th>RH</th>
<th>Corn EMC</th>
<th>1.0 cfm/bu</th>
<th>1.25 cfm/bu</th>
</tr>
</thead>
<tbody>
<tr>
<td>Apr</td>
<td>42</td>
<td>65%</td>
<td>15.3%</td>
<td>51</td>
<td>41</td>
</tr>
<tr>
<td>+5°F</td>
<td>47</td>
<td>54%</td>
<td>13.3%</td>
<td>46</td>
<td>37</td>
</tr>
<tr>
<td>May</td>
<td>56</td>
<td>60%</td>
<td>13.5%</td>
<td>43</td>
<td>34</td>
</tr>
</tbody>
</table>

Natural air drying is very efficient in the spring. Start fans when outdoor temperatures average about 40 F.
## Natural Air Drying Soybeans

Final Moisture Content ≈ 11%  
Airflow Rate = 1.0 cfm/bu.

<table>
<thead>
<tr>
<th>Month</th>
<th>Temp °F</th>
<th>R.H. %</th>
<th>Initial Soybean Moisture Content</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>20%</td>
</tr>
<tr>
<td></td>
<td>+3F Fan</td>
<td></td>
<td>Dry</td>
</tr>
<tr>
<td>April</td>
<td>45</td>
<td>63%</td>
<td>60</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>May</td>
<td>59</td>
<td>58%</td>
<td>39</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>June</td>
<td>68</td>
<td>60%</td>
<td>39</td>
</tr>
</tbody>
</table>

Maximum moisture content for air drying is about 15% to 16% with an airflow rate of at least 1.0 cfm/bu. Start drying when outdoor temperature averages about 40°F.
Temperature and Humidity

Fargo, North Dakota

Lansing, Michigan

Average Temperatures

Humidity

City morning
City afternoon
US morning average
US afternoon average
WARNING

Condensation may freeze over vents when outside air temperatures are near or below freezing

Iced over vents will damage bin

Leave fill and access open

Pressure Switch
Fans Off During Snow/Rain/Fog
High Temperature Drying Soybeans

- Follow dryer recommendations to start then adjust as appropriate

- Typical Maximum Drying Temperature (non-food soybeans)
  - Continuous flow: 120-130° F
  - Batch Dryer: 110° F
  - Seed: 110° F

- Relative humidity above 40% reduces cracks ≈ 20°F temperature increase.
**Damage Occurring to Soybeans as Function of Drying Temperature**

<table>
<thead>
<tr>
<th>Drying Temperature (°F)</th>
<th>Skins Cracked (%)</th>
<th>Beans Cracked (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>100</td>
<td>10 – 60</td>
<td>5 – 20</td>
</tr>
<tr>
<td>130</td>
<td>50 – 90</td>
<td>20 – 70</td>
</tr>
<tr>
<td>160</td>
<td>80 – 100</td>
<td>30 – 80</td>
</tr>
</tbody>
</table>
Fire Hazard Drying Soybeans

- Pods and trash become lodged and combustible
- Keep grain flowing
- Keep dryer clean
- Monitor dryer
Cool Grain to Prevent Storage Problems

**Optimum for Insects and Spoilage**

- Grain Temperature
- Air Temperature

**Insect Reproduction Reduced**

**Insects Dormant**

- Grain Temperature 35-40°F

**Insects Killed**

20-25°F

* Prevent crusting due to moisture migration by cooling grain to within 15°F of average outdoor temperatures.
* Cooling grain by 10°F doubles its allowable storage time.
Spring Grain Cooling

Solar Radiation (Btu/ft$^2$-day)

<table>
<thead>
<tr>
<th></th>
<th>Wall</th>
<th>Roof</th>
</tr>
</thead>
<tbody>
<tr>
<td>Feb. 21</td>
<td>1725</td>
<td>1800</td>
</tr>
<tr>
<td>Jun. 21</td>
<td>800</td>
<td>2425</td>
</tr>
</tbody>
</table>

Minimum Temperature

<table>
<thead>
<tr>
<th>ND</th>
<th>Average Temperature</th>
<th>Minimum Temperature</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mar</td>
<td>25</td>
<td>16</td>
</tr>
<tr>
<td>Apr</td>
<td>41</td>
<td>29</td>
</tr>
<tr>
<td>May</td>
<td>55</td>
<td>43</td>
</tr>
</tbody>
</table>

Periodically Cool!
### North Central Region States

**Average Monthly Maximum and Minimum Temperature, °F**

<table>
<thead>
<tr>
<th></th>
<th>ND</th>
<th>SD</th>
<th>NE</th>
<th>KS</th>
<th>MN</th>
<th>IA</th>
<th>MO</th>
<th>WI</th>
<th>IL</th>
<th>MI</th>
<th>IN</th>
<th>OH</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Jan</strong>&lt;br&gt;Max</td>
<td>16</td>
<td>27</td>
<td>36</td>
<td>39</td>
<td>19</td>
<td>31</td>
<td>38</td>
<td>23</td>
<td>36</td>
<td>30</td>
<td>32</td>
<td>36</td>
</tr>
<tr>
<td><strong>Min</strong>&lt;br&gt;-3</td>
<td>7</td>
<td>14</td>
<td>19</td>
<td>-1</td>
<td>14</td>
<td>21</td>
<td>6</td>
<td>19</td>
<td>17</td>
<td>16</td>
<td>20</td>
<td></td>
</tr>
<tr>
<td><strong>April</strong>&lt;br&gt;Max</td>
<td>52</td>
<td>59</td>
<td>63</td>
<td>67</td>
<td>55</td>
<td>62</td>
<td>66</td>
<td>55</td>
<td>66</td>
<td>58</td>
<td>62</td>
<td>63</td>
</tr>
<tr>
<td><strong>Min</strong>&lt;br&gt;29</td>
<td>34</td>
<td>38</td>
<td>43</td>
<td>34</td>
<td>41</td>
<td>44</td>
<td>33</td>
<td>43</td>
<td>37</td>
<td>38</td>
<td>41</td>
<td></td>
</tr>
<tr>
<td><strong>July</strong>&lt;br&gt;Max</td>
<td>80</td>
<td>86</td>
<td>88</td>
<td>93</td>
<td>82</td>
<td>86</td>
<td>88</td>
<td>80</td>
<td>87</td>
<td>82</td>
<td>84</td>
<td>85</td>
</tr>
<tr>
<td><strong>Min</strong>&lt;br&gt;57</td>
<td>61</td>
<td>65</td>
<td>69</td>
<td>61</td>
<td>67</td>
<td>67</td>
<td>59</td>
<td>66</td>
<td>61</td>
<td>62</td>
<td>65</td>
<td></td>
</tr>
<tr>
<td><strong>Oct</strong>&lt;br&gt;Max</td>
<td>55</td>
<td>60</td>
<td>65</td>
<td>70</td>
<td>58</td>
<td>63</td>
<td>67</td>
<td>55</td>
<td>68</td>
<td>60</td>
<td>64</td>
<td>65</td>
</tr>
<tr>
<td><strong>Min</strong>&lt;br&gt;32</td>
<td>35</td>
<td>40</td>
<td>46</td>
<td>36</td>
<td>43</td>
<td>45</td>
<td>37</td>
<td>45</td>
<td>41</td>
<td>41</td>
<td>44</td>
<td></td>
</tr>
</tbody>
</table>
Cool Stored Soybeans

- Free fatty acids increase with moisture, temperature, and time
- Storage of 12% beans @ 70 F < 4 months to exceed free fatty acid acceptable level.
- Cool to 20 - 30 F for winter
- Keep as cool as possible spring & summer
Calculate Aeration Time

Cooling Time

Time (hrs.) = 15 / Airflow rate (cfm/bu.)
Time (hrs.) = 15 / 0.2 cfm/bu.
Time (hrs.) = 75 hrs.

Example:
42’ diameter, 36 ft. depth, 40,000 bu. of Soybeans
5 hp. LSC Fan, 0.21 cfm/bu.
Cooling time = 72 hrs.
Fan Selection Program

University of Minnesota Fan Selection for Grain Bins

Background

Settings

Bin and Crop Inputs

Select a crop: Barley
Floor Type: Full
Bin Diameter, feet: 21
Grain Depth, feet: 20
Desired airflow (cfm/bu): 1

Estimated Fan Requirements

(to get desired airflow when bin is full)
Bin capacity (bushels):
Total airflow (cfm):
Estimated static pressure (inches of water):
Estimated fan power needed (hp):

Fan Selection

Select a fan: 0.33 hp AEROVENT 1240-0W | 12" (Axial)
Fan arrangement: Parallel
Number of fans on bin: 1

Results

Airflow vs Depth Table  Airflow Graph  System Graph
Cover Fans When Not Operating

- Keep snow & pests out
- Prevents spring warm-up
- Keep damp air out
Ventilate Bin Headspace
Grain Handling & Storage Safety
Keep clear of all augers. **DO NOT ENTER this bin!**

If you must enter the bin:
1. Shut off and lock out all power.
2. Use a safety harness and safety line.
3. Station another person outside the bin.
4. Avoid the center of the bin.
5. Wear proper breathing equipment or respirator.

**Failure to heed these warnings could result in serious injury or death**
2010 Spike Due to Wet Grain

Figure 6: Number of annual grain entrapment cases recorded between 2004 and 2014.
Middle Age Risk

Figure 7: Age distribution of 2014 grain entrapment victims by number of cases recorded.
Bridging
Grain Columns
#1 Cause – Rodding With Unload Conveyor Running
Speed of Entrapment

Based on a 10-inch auger unloading at a rate of 4,086 bushels per hour.
Cannot Pull Out!
Lifeline System Set-up

A sidewall anchor is NEVER attached to any part of the inside bin ladder. The inside bin ladder was omitted from this drawing for illustrative purposes.

Note: Figures above are for detailed reference ONLY and are NOT drawn to scale. The bin access ladder, cage, platform, roof and other structural elements are for illustrative purposes ONLY and as drawn may not comply fully with OSHA standards or have detail.

www.grainsafety.org
Grain Engulfment Prevention System
Lockout / Tagout – IS A MUST!
Start Aeration
Call for Help!
What happens when enter bin?
Remove Grain

Cut holes at equal distance around the bin, below the victim, to release the grain on all sides.

30 - 40” (75-100 cm) Across
Rescue Tube
Silo Unloading - Center First
Off Center Unloading
Bin Collapsing
Bin Sweeps
Grain Dust Hazard

Exposure to grain dust produces asthma, other respiratory effects (e.g., cough, rhinitis, and farmers lung), and nonpulmonary disorders (e.g., conjunctivitis, grain fever, and dermatitis). Though thorough characterization of allergenicity (Type I, IgE-mediated) is lacking, occupational exposure to grain dust has clearly been associated with potent systemic immunologic responses that evoke inflammatory responses of smooth muscle in the airways.
Moldy Grain Health Hazard

At least a N95 rating
Fall Hazards
For More Information

Internet Search: NDSU Grain Drying and Storage

EXTENDING KNOWLEDGE >> CHANGING LIVES