On-Farm Grain Storage

*Is It Your Weakest Link?*

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Engineering Specialist, Crop Systems and Environment
FarmSmart 2017 - Guelph
# Ontario Grain Storage by the Numbers

<table>
<thead>
<tr>
<th>Year</th>
<th>On-Farm Storage</th>
<th>Commercial Storage</th>
</tr>
</thead>
<tbody>
<tr>
<td>1999</td>
<td>2,750,000 tonnes</td>
<td>4,200,000 tonnes</td>
</tr>
<tr>
<td>2014</td>
<td>9,439,000 tonnes</td>
<td>5,887,000 tonnes</td>
</tr>
</tbody>
</table>

**Growth**

- On-Farm Storage: 3.4x
- Commercial Storage: 1.4x

Data source: Agricorp, Statistics Canada, OABA
Deliver

Price

Max.

At

Corn*

*or beans, wheat, etc…
The **GOLDEN RULE** of Grain Storage

You can’t **IMPROVE** grain quality in the bin...

... but you **CAN** make it worse
Storage Quality Factors

- Dry
- Core/Clean
- Aerate
- Monitor
- Protect

Graph showing the relationship between Grain Temperature (°C) and Grain Moisture (%) with different zones and conditions:
- Safe Storage Zone
- Insect Heating
- Germination Diseases
- Fungal Heating
- Mite Attack
### Maximum recommended moisture contents for safe storage

<table>
<thead>
<tr>
<th>Crop</th>
<th>Short term (less than 6 months)</th>
<th>Long term (more than 6 months)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Barley</td>
<td>14 %</td>
<td>12 %</td>
</tr>
<tr>
<td>Corn</td>
<td>15.5</td>
<td>13</td>
</tr>
<tr>
<td>Edible Beans</td>
<td>16</td>
<td>13</td>
</tr>
<tr>
<td>Flax seed</td>
<td>9</td>
<td>7</td>
</tr>
<tr>
<td>Millet</td>
<td>10</td>
<td>9</td>
</tr>
<tr>
<td>Oats</td>
<td>14</td>
<td>12</td>
</tr>
<tr>
<td>Rye</td>
<td>13</td>
<td>12</td>
</tr>
<tr>
<td>Sorghum</td>
<td>13.5</td>
<td>13</td>
</tr>
<tr>
<td>Soybeans</td>
<td>13</td>
<td>11</td>
</tr>
<tr>
<td>Non-Oil Sunflower</td>
<td>11</td>
<td>10</td>
</tr>
<tr>
<td>Oil Sunflower</td>
<td>10</td>
<td>8</td>
</tr>
<tr>
<td>Wheat</td>
<td>14</td>
<td>13</td>
</tr>
</tbody>
</table>

Source: NDSU Publ. AE701 “Grain Drying”
Allowable Storage Time for Cereals

Source: NDSU
Allowable Storage Time

Allowable Storage Time for Shelled Corn

Source: USDA Research, Iowa State University; Transactions of ASAE 333-337
Allowable Storage Time

Allowable Storage Time for Soybeans

Grain Temperature (°C)

Allowable Storage Time (days)

Spoils faster  Spoils slower

Source: NDSU
Tweaking Drying Temperature

• Measure harvest test weight
• Set plenum temperature, begin drying
  → Measure dried test weight
• Reduce plenum temperature 10°F
  → Measure dried test weight again
• If test weight increasing → reduce 10°F
• When dried test weight doesn’t change → increase plenum temp 10°F

GOAL: Slower drying = HIGHER QUALITY

Source: John Gnadke, Advanced Grain Systems Inc. 515 964-9885
Fines

- Dry
- Core/Clean
- Aerate
- Monitor
- Protect
Coring Bins

- Fines collect in centre
- What to do with fines:
  - Feed
  - Sell
  - Clean

Source: University of Minnesota
Bin Flow

- **Dry**
- **Core/Clean**
- **Aerate**
- **Monitor**
- **Protect**

**SHORT**
(H < 1.5x W)

- **Funnel Flow**

**TALL**
(H > 1.5x W)

- **Plug Flow**

**HOPPER**

- **Mass Flow**
Cleaning Grain

Size separation
• Screener-Scalpers
• Vibratory
• Rotary
• Drag-Scalpers

Density separation
• Aspirators
Rule of thumb:
For every **2-3% increase** in damaged kernels, **0.5% weight is lost**.

Corn average:
**0.5% breakage per elevation**
Grain Breakage

MORE

- High speeds
- High drop heights
- Small spouts
- High-temp-dried
- Colder
- Very dry

LESS

- Slow speeds
- Low drop heights
- Large spouts
- Low-temp-dried
- Warmer
- Wetter ***
How much do you handle your grain?
**Why Aerate?**

**REMOVE** field heat

**EQUALIZE MOISTURE** in the bin

**PREVENT CONVECTIVE AIR MOVEMENT** within the grain mass

**CRITICAL** to long-term storage
Equilibrium Moisture Content

... the moisture level grain will reach when exposed to air at a certain temperature and relative humidity
### EMC Chart – Corn

**Target: 15.5% moisture**

<table>
<thead>
<tr>
<th>Air Temperature (°C)</th>
<th>EMC (% wet basis) at Relative Humidity</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>50%</td>
</tr>
<tr>
<td>0</td>
<td>13.7</td>
</tr>
<tr>
<td>5</td>
<td>13.1</td>
</tr>
<tr>
<td>10</td>
<td>12.5</td>
</tr>
<tr>
<td>15</td>
<td>11.9</td>
</tr>
<tr>
<td>20</td>
<td>11.5</td>
</tr>
<tr>
<td>25</td>
<td>11.0</td>
</tr>
</tbody>
</table>
# EMC Chart – Soybeans

## Target: 13% moisture

<table>
<thead>
<tr>
<th>Air Temperature (°C)</th>
<th>EMC (% wet basis) at Relative Humidity</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>50%</td>
</tr>
<tr>
<td>0</td>
<td>10.0</td>
</tr>
<tr>
<td>5</td>
<td>9.8</td>
</tr>
<tr>
<td>10</td>
<td>9.5</td>
</tr>
<tr>
<td>15</td>
<td>9.2</td>
</tr>
<tr>
<td>20</td>
<td>9.0</td>
</tr>
<tr>
<td>25</td>
<td>8.7</td>
</tr>
</tbody>
</table>
## EMC Chart – Soft Winter Wheat

**Target: 14% moisture**

<table>
<thead>
<tr>
<th>Air Temperature (°C)</th>
<th>EMC (% wet basis) at Relative Humidity</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>50%</td>
</tr>
<tr>
<td>0</td>
<td>12.5</td>
</tr>
<tr>
<td>5</td>
<td>12.1</td>
</tr>
<tr>
<td>10</td>
<td>11.7</td>
</tr>
<tr>
<td>15</td>
<td>11.4</td>
</tr>
<tr>
<td>20</td>
<td>11.1</td>
</tr>
<tr>
<td>25</td>
<td>10.8</td>
</tr>
</tbody>
</table>
EMC Chart – Hard Winter Wheat

**Target: 14% moisture**

<table>
<thead>
<tr>
<th>Air Temperature (°C)</th>
<th>EMC (% wet basis) at Relative Humidity</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>50%</td>
</tr>
<tr>
<td>0</td>
<td>13.6</td>
</tr>
<tr>
<td>5</td>
<td>13.1</td>
</tr>
<tr>
<td>10</td>
<td>12.7</td>
</tr>
<tr>
<td>15</td>
<td>11.7</td>
</tr>
<tr>
<td>20</td>
<td>12.1</td>
</tr>
<tr>
<td>25</td>
<td>11.8</td>
</tr>
</tbody>
</table>
www.weathercentral.ca/bincast.cfm

10-day forecasts of air temperature, relative humidity **and EMC**

Answer the age-old question:

“*When do I turn on my fan???”*
When should I turn my fan on?

BiNcast helps by providing you with the predicted equilibrium moisture content (EMC) for your bin for the next 5 days. Zoom into your location and choose your grain type. You may also search for your location by address or GPS coordinates using the search form below.
**Grain**: shelled corn

**Location**: 43.54480°N, -80.24817°W

<table>
<thead>
<tr>
<th>Date Time</th>
<th>Temp (°C)</th>
<th>RH (%)</th>
<th>Equilibrium Moisture Content (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tue. at 9 AM</td>
<td>0.0</td>
<td>94</td>
<td>25.1</td>
</tr>
<tr>
<td>Tue. at 10 AM</td>
<td>0.2</td>
<td>94</td>
<td>25.1</td>
</tr>
<tr>
<td>Tue. at 11 AM</td>
<td>0.3</td>
<td>95</td>
<td>25.6</td>
</tr>
<tr>
<td>Tue. at 12 PM</td>
<td>0.3</td>
<td>94</td>
<td>25.0</td>
</tr>
</tbody>
</table>
Fan Control Options

Computerized
Fan Control Options

Humidistat
Fan Control Options

Timer

- Dry
- Core/Clean
- Aerate
- Monitor
- Protect
Convective Air – Cold Weather

Dry

Core/Clean

Aerate

Monitor

Protect
Convective Air – Warm Weather

- Warm Air
- Core/Clean
- Aerate
- Monitor
- Protect
## Time Needed to Change Grain Temp.

<table>
<thead>
<tr>
<th>Airflow Rate</th>
<th>Grain Cooling Time (hrs.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>L/s/m³</td>
<td>Fall</td>
</tr>
<tr>
<td>0.65</td>
<td>300</td>
</tr>
<tr>
<td>1.3</td>
<td>150</td>
</tr>
<tr>
<td>2.6</td>
<td>75</td>
</tr>
<tr>
<td>3.2</td>
<td>60</td>
</tr>
<tr>
<td>4.3</td>
<td>45</td>
</tr>
<tr>
<td>6.5</td>
<td>30</td>
</tr>
<tr>
<td>9.7</td>
<td>20</td>
</tr>
<tr>
<td>13.0</td>
<td>15</td>
</tr>
</tbody>
</table>

Aerate every time the *average* outdoor temperature changes 8-10°C
Understand fan airflow

CFM = cubic feet per minute
L/s = litres per second

<table>
<thead>
<tr>
<th>Fan HP</th>
<th>Static pressure (inches of water column)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0</td>
</tr>
<tr>
<td>3</td>
<td>5,300</td>
</tr>
<tr>
<td>5</td>
<td>9,500</td>
</tr>
<tr>
<td>7 ½</td>
<td>12,000</td>
</tr>
</tbody>
</table>
Understand static pressure

U-tube manometer

**Diagram:**
- **Static Pressure (Vertical distance in mm):**
  - $1 \text{ mm} = 10 \text{ Pa}$
- **Air Duct or Plenum**
- **Glass "U" Tube with Water**

- **Key Elements:**
  - **Dry**
  - **Core/Clean**
  - **Aerate**
  - **Monitor**
  - **Protect**
Bin Fan Selector Tool

http://webapps.bbe.umn.edu/fans/

**Input:**
- Grain type
- Bin size
- Desired airflow (CFM/bu)
- Fan size (if known)

**Output:**
- Required fan size
- Estimated static pressure
- Estimated Fan HP
- Airflow at various depths
Bin Fan Selector Tool

Settings

Bin and Crop Inputs

Select a crop: Shelled corn
Floor Type: Full
Bin Diameter, feet: 30
Grain Depth, feet: 25
Desired airflow (cfm/bu): 0.5

Estimated Fan Requirements

Bin capacity (bushels): 14,137
Total airflow (cfm): 7,069
Estimated static pressure (inches of water): 2.63
Estimated fan power needed (hp): 4.87

Fan Selection

Select a fan: 5 hp GSI CF-5 | 1750 rpm (Centrif.)
Fan arrangement: Parallel
Number of fans on bin: 1

Dry
Core/Clean
Aerate
Monitor
Protect
Crop: Shelled corn; Bin Diameter, feet: 30
Floor: Full
Airflow, cfm/bu: 0.5
Fan: 1 - 5 hp GSI CF-5 | 1750 rpm (Centrif.) arranged in Parallel

Airflow is within 5% of desired value.

<table>
<thead>
<tr>
<th>Depth (ft)</th>
<th>Bushels</th>
<th>Airflow (cfm)</th>
<th>Airflow (cfm/bu)</th>
<th>S.P. (in. H2O)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>1,131</td>
<td>9,331</td>
<td>8.25</td>
<td>0.31</td>
</tr>
<tr>
<td>4</td>
<td>2,262</td>
<td>9,170</td>
<td>4.05</td>
<td>0.60</td>
</tr>
<tr>
<td>6</td>
<td>3,393</td>
<td>9,016</td>
<td>2.66</td>
<td>0.88</td>
</tr>
<tr>
<td>8</td>
<td>4,524</td>
<td>8,791</td>
<td>1.94</td>
<td>1.13</td>
</tr>
<tr>
<td>10</td>
<td>5,655</td>
<td>8,522</td>
<td>1.51</td>
<td>1.36</td>
</tr>
<tr>
<td>12</td>
<td>6,786</td>
<td>8,275</td>
<td>1.22</td>
<td>1.56</td>
</tr>
<tr>
<td>14</td>
<td>7,917</td>
<td>8,045</td>
<td>1.02</td>
<td>1.75</td>
</tr>
<tr>
<td>16</td>
<td>9,048</td>
<td>7,831</td>
<td>0.87</td>
<td>1.93</td>
</tr>
<tr>
<td>18</td>
<td>10,179</td>
<td>7,646</td>
<td>0.75</td>
<td>2.10</td>
</tr>
<tr>
<td>20</td>
<td>11,310</td>
<td>7,481</td>
<td>0.66</td>
<td>2.27</td>
</tr>
<tr>
<td>22</td>
<td>12,441</td>
<td>7,324</td>
<td>0.59</td>
<td>2.43</td>
</tr>
<tr>
<td>24</td>
<td>13,572</td>
<td>7,176</td>
<td>0.53</td>
<td>2.57</td>
</tr>
<tr>
<td>25</td>
<td>14,137</td>
<td>7,105</td>
<td>0.50</td>
<td>2.64</td>
</tr>
</tbody>
</table>
Aerate to prevent insect problems

Adapted from Dr. Kenneth Hellevang P.E., North Dakota State University Extension Service
Monitor bins OFTEN

- Check bins **REGULARLY**, minimum monthly

- Use your **EYES** to evaluate the grain
  - Colour: bright (not dusty or dull)
  - Moisture on the underside of the bin roof?
  - Signs of insects?

- Use your **NOSE** to pick up off odours

- Check static pressure below the aeration floor

- Keep **WRITTEN RECORDS** of inspections
Monitoring tools

- Dry
- Core/Clean
- Aerate
- Monitor
- Protect
Catching grain bugs

Dry
Core/Clean
Aerate
Monitor
Protect
Catching grain bugs

Dry

Core/Clean

Aerate

Monitor

Protect
Catching grain bugs

- Dry
- Core/Clean
- Aerate
- Monitor
- Protect
“Seeing insects in the grain when you are loading the truck may be *TOO LATE* to do anything”
Common stored grain insects

- Indian meal moth*
- Rusty grain beetle*
- Granary weevil
- Lesser grain borer
- Grain lice
- Grain mites

*Malathion resistant!
Eight common insect pests

Insect identification tool
Protect your value

...stuff happens

Have a backup plan.
Production Insurance (Agricorp)

...only during the period from seeding or planting until harvest

...loss or damage due to storage conditions is not insured.
Produce Insurance (private)

Extension of farm insurance

Covers crop in transport, storage from harvest to point of sale

“Named perils” vs “broad coverage”
Named Perils (example)

- Fire
- Lightning
- Explosion
- Smoke
- Windstorm
- Hail
- Riot
- Earthquake
- Building collapse
- Flood
- Collision / derailment / upset
- Impact by vehicle
- Theft
- Vandalism

What’s missing??

- insects
- poor management
Protect yourself

- No loose clothing
- Safety boots
- Safety glasses
- Hard hat
- Gloves
- Hearing protection
- Respirator
- Lock out / tag out
- Safety harness & tether
- Bin entry protocol
- Whistle
- Cell phone
- **BIN BUDDY**
Force to free 160-lb person from waist-deep grain:

**325 lbs**

Human pulling force:

**100-150 lbs max**
Summary

Deliver » **Dry** grain to preserve it from spoilage
Corn » **Core** bins to remove fines
At » **Aerate** to maintain bin conditions
Max. » **Monitor** to avoid problems developing
Price » **Protect** value with insurance

You can’t **IMPROVE** grain quality in the bin…

… work to maintain the quality you have.

Thank you!

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james.dyck@ontario.ca