Maintaining Grain Quality in Storage

Klein Ileleji, PhD.
Associate Professor & Extension Engineer
Agricultural and Biological Engineering

Post-Harvest Update and Recertification Workshop
December 16, 2013
Beck Ag. Center, West Lafayette, Indiana
Presentation Outline

- 2013 Corn and Soybean Quality Brief
- Emerging Issues
- Basics of Stored Grain Management
- Application of S.L.A.M.
2013 Corn & Soybean Quality

- Overall it was a good year for both crops
- Crop harvested timely came out of field with good storage characteristics
- Crops harvested late in November where hit by frost and rewetting which created field variability in moisture and difficult drying conditions
Emerging Issues

- Increased cases of bin entrapment/engulfment
- Increased on-farm storage capacity
- Managing grain quality in a bad year
- High levels of CO$_2$ emitted from wet corn in 2013
- Effective and safe monitoring of stored grain in silos and grain piles
Figure 1: Number of annual grain entrapments recorded in the National Grain Entrapment Database and the 5-year average between 2001 and 2010.

Entrapments by Geographic Location

Source: Dr. Sam McNeill, University of Kentucky

1964-2007
N = 719

1 - Unknown Location
Documented Contributing Factors

- No. 1 identified cause of entrapment was out-of-condition grain
- High capacity grain handling systems
- Working alone
- Relaxed compliance with workplace safety regulations
- Lack of knowledge concerning the risk
The Major cause of grain entrapments

- There continues to be a direct relationship between ‘out-of-condition’ or spoiled grain, and greater probability of entrapment (Riedel and Field, 2010)

U.S. On-Farm Storage Capacity

Data Source: USDA-NASS, 2013
Grain Post-Harvest Team
U.S. Off-Farm Storage Capacity

Data Source: USDA-NASS, 2013
Grain Post-Harvest Team
How do you manage quality in a bad crop year?

• 2009 was a bad crop year with several challenges:
  – Wet conditions made harvest a challenge.
  – Field damaged corn from ear rot, etc. made post-harvest handling a challenge.
  – Higher levels of mycotoxin and mold in corn from the field made storage a challenge.
  – Higher levels of fines and broken corn

2013 was a good crop year !!!
CO₂ Emitted from Wet Corn

High-Moisture Levels in Some New-Crop Corn Deliveries May Warrant Atmospheric Testing to Protect Employees – NGFA, 2013

• Isolated incidents where the post-harvest respiration of some new-crop harvested corn appears to be occurring rapidly after unloading; thus, leading to elevated levels of carbon dioxide (CO₂) and depleted oxygen levels -- particularly in low-lying storage areas - both at farms and commercial facilities.
Challenges in Large Grain Stock Management

- On-farm bin sizes installed are larger in capacity.
- Most farm bins have no monitoring tool.
- When a monitoring tool is available, typically a temperature cable, it is not enough for effective management.
- Lack of effective management of large grain stocks.
Basic Concepts of Stored Grain Management

- Grain is a biologically active material and therefore it will deteriorate in storage under favorable conditions.

- Stored grain quality cannot be improved but maintained.

- Therefore, knowing the history and initial grain quality is an important first step in managing grain in storage.

Grain Quality after Storage = F(Quality_{T_s}, Mgt, ?)

How can we accurately predict this?
Your Investment in Storage

Maintaining Quality is Job # 1 in Stored Grain Management
The Stored Grain Ecosystem

- **Grain**
- **Temperature**
- **Grain moisture & RH**
- **Gases: CO₂ & O₂**
- **Solar radiation, precipitation, etc.**
- **Phy., chem. & biol. controls**
- **Mold & Mycotoxins**
- **Contaminants: frass, faeces, etc.**
- **Insects, mites, rodents, birds**
- **Other plant materials**
Factors that Affect Grain Spoilage in Storage

Grain deterioration of stored grain depends on

- Moisture, broken kernel, fines and foreign material
- Initial storage mold infestation
- Initial insect pest infestation and insect pest type
- Grain quality (presences of fines/intact kernels)
- Sanitation
- Stored grain environment
  - Temperature and Relative Humidity (RH)
  - CO₂ and O₂
- Stored Grain Management
# Storage Life of Grain

<table>
<thead>
<tr>
<th>Corn temperature °F</th>
<th>Moisture Content</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Corn (top %), Soybean (bottom %)</td>
</tr>
<tr>
<td></td>
<td>13%, 11%</td>
</tr>
<tr>
<td>40</td>
<td>150</td>
</tr>
<tr>
<td>50</td>
<td>84</td>
</tr>
<tr>
<td>60</td>
<td>47</td>
</tr>
<tr>
<td>70</td>
<td>26</td>
</tr>
<tr>
<td>80</td>
<td>15</td>
</tr>
</tbody>
</table>

*Based on 0.5% maximum dry matter loss—calculated on the basis of USDA research at Iowa State University. Corresponds to one grade number loss; 2-3% points in damaged seeds. Soybean approximated at 2% lower moisture than corn.

Safe Grain Moisture Content (ERH = 65%)

Source: Dr. Dirk Maier, Kansas State University
The concept of SLAM for stored grain systems was developed in the 1990s by Purdue University Extension Engineer and Specialists: Dr. Dirk Maier (Agricultural Engineer), Dr. Linda Mason (Stored-Product Entomologist) and Dr. Charles Woloshuk (Stored-Product Pathologist).

Acknowledgements:
Thanks to Dr. Linda Mason, Purdue Entomology Department and Dr. Dirk Maier, Department Head at Kansas State University Grain Science Program and Mr. Dave Crompton, Integris USA, LLC. for providing the contents of this presentation.
Sanitation
Think Insect Clean!
Eliminate Insect Harborage –
under floor sanitation, cracks and crevices
Clean Roof Vents to Prevent Aeration Problems
Pest Prevention

Empty Bin Treatment

External Spray

Internal Spray

US-Nigeria Commodity Storage Workshop
Loading

Eliminate the potential for loading by:

- Cleaning grain to remove fines and foreign material
- Drying grain gently by using appropriate drying techniques to prevent stress cracks
- Handling gently using appropriate grain conveying devices
Pre-Cleaning
Cushion Boxes and Flow Retarders
Bin Entrapment Rescue in Spring 2005

What do you think was the cause of this event?
• Core of fines
  – Foreign Material (FM)
  – Broken grain & fines
  – Weed seeds
Aerate – to slow down bio-activity
# Temperature Influence on Insects Fields, 1992

<table>
<thead>
<tr>
<th>Temperature (°F)</th>
<th>Effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>122+</td>
<td>Death in minutes</td>
</tr>
<tr>
<td>95+</td>
<td>Development stops</td>
</tr>
<tr>
<td>77-90</td>
<td>Optimum</td>
</tr>
<tr>
<td>66-77</td>
<td>Sub-optimum</td>
</tr>
<tr>
<td>41-60</td>
<td>Death in days</td>
</tr>
<tr>
<td>0</td>
<td>Death in minutes</td>
</tr>
</tbody>
</table>
Cool Grain to Prevent Storage Problems

Optimum for Insects and Spoilage

Insect Reproduction Reduced

Insects Dormant

Insects Killed

Grain Temperature 35-40°F

20-25°F

Aerate

Temperature (°F)

Aug Sept Oct Nov Dec Jan Feb Mar Apr May June July

Temperatures for Upper Midwest

* 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.

Source: Dr. Kenneth Hellevang, North Dakota State University

US-Nigeria Commodity Storage Workshop
Move **Aeration Front** through grain mass as quickly as possible!

Depends on Air EMC and Airflow
Aeration Phases

• **Phase 1: Fall Cool Down**
  – Lower grain temperatures stepwise
    • October – 40-45°F
    • November – 35-40°F
    • December – 28-35°F

• **Phase 2: Winter Maintenance**
  – Maintain low temperatures with intermittent aeration:
    January, February - 28-35°F

• **Phase 3: Spring Holding**
  – Keep grain cold from winter aeration
    • Seal fans
    • Ventilate only headspace intermittently

Source: Dr. Dirk Maier, Kansas State University

US-Nigeria Commodity Storage Workshop

No Summer Aeration to warm-up grain!
Open Fan

Sealed Fan

US-Nigeria Commodity Storage Workshop
Headspace Ventilation
Grain bulk temperature - 2001

Storage Period

Temperature (°C)

No-Aeration-Trial 2001 (avg. of 3 bins)
Ambient Aeration-Trial 2001 (avg. of 4 bins)
Chilled Aeration-Trial 2001 (avg. of 4 bins)

- 23.9°C
- 18.3°C
Probe Trap Data - 2001

Storage Time

Insect numbers per day (NA)
(NA) Non-Aeration-Trial 2001 (avg. of 3 bins)
(AA) Ambient Aeration-Trial 2001 (avg. of 4 bins)
(CA) Chilled Aeration-Trial 2001 (avg. of 4 bins)
Monitoring:

You can’t manage what you don’t know is there
2-D Graph;
Complete picture of what happened over time.
Monitor temperature with temperature cables

It takes a while to detect deterioration and hot spots using temperature cables alone
Temperature – 21.23% mc

Response of mold to temperature rise at 21.23% m.c. at 25 ºC

- Non-insulated - 21.23% mc
- Insulated -21.23% mc
- Chamber temperature
Temperature – 14.60% mc

Response of mold to temperature rise at 14.60% m.c. at 25 °C

- Non-insulated - 14.60% mc
- Insulated -14.60% mc
- Chamber temperature
Mold counts (CFUs) - 25°C

Effect of hermetic storage on mold counts at 25°C

Mold counts (CFUs)

- 10.80%
- 14.60%
- 17.77%
- 21.23%

Time (Months)
Grain & Ambient Temp Difference

Temperature difference from ambient conditions 25 °C - 21.23% mc

Biomass Logistics and Particle Technology Group
Grain & Ambient Temp Difference

*Temperature difference from ambient conditions 25 °C - 14.60% mc*

- **Non-insulated**
- **Insulated**
Monitored CO₂ levels during storage

Carbon dioxide levels in hermetic storage at 25 °C

Early detection of bio-activity

10.80%  14.60%  17.77%  21.23%
Insect Monitoring – Pitfall trap

Grain Post-Harvest Team
Real-time Insect Detection System

As the insect breaks the Infrared beams, its size is registered. At the same time, the time and temperature is captured in the memory on the built-in microprocessor.

Available from: www.opisystems.com/ Integris USA, LLC.
Insect monitoring - Pheromone flight trap
CO$_2$ Monitors – Early Spoilage Detection
The Andersons, Delphi - Tank 54 (Semi-wet 17.5% MC)

Total CO2 (kg)

- 53.7 kg (May 28)
- 178.2 kg (June 09)
- 283.5 kg (June 24)

Early Detection!

- April 17
- April 24
- 53.7 kg (May 28)
- 178.2 kg (June 09)
- 283.5 kg (June 24)
Spoilage in Tank 54
Experimental Set-up

- Wind vane
- Water dripped
- CO₂ sensor
- Field Point module
- Thermocouple
- RH probe
- Hot spot module
- Temperature cable
- Corn
- PC – LabVIEW VI
- Fan

Post-Harvest Education and Research Center, Purdue University
CO2 Detection during Corn Storage
CO₂ and Hot spot Temperature Data
CO₂ concentration in the headspace of PHERC pilot bin 16 due to a hot spot (10/27/01-11/5/01)
CO$_2$ concentration in the headspace of PHERC pilot bin 16 due to a hot spot (10/27/01-11/5/01)
Hot spot core at the center of bin 16 caused by leakage
Grain Susceptibility to Spoilage Test

**CO₂ Test Methods**

- Re-wetting (24 hr equilibration):
  - to 21% moisture
  - to 16% moisture
- Place in 1 pint air-tight jars
- Incubate at 23°C or 30°C
- 47 & 72 hrs, remove lid for 1 hr
- 48 & 72 hrs, insert indicator paddles, read hourly (color cards, DCR)
- Final Moisture content
- Dry remainder at 30°C for ergosterol & NIR

**Source:** Dr. Richard Stroshine, Purdue University
MC, Temperature effects: Paddle reading at 24°C, two m.c.’s

Source: Dr. Richard Stroshine, Purdue University
Resources

Some Extension websites from U.S. Land-Grant Universities:

• [http://extension.entm.purdue.edu/grainlab/](http://extension.entm.purdue.edu/grainlab/)
• [http://www.extension.iastate.edu/Grain/](http://www.extension.iastate.edu/Grain/)
• [http://www.oardc.ohio-state.edu/nc213/](http://www.oardc.ohio-state.edu/nc213/)
• [http://uarpp.uark.edu/personnel.htm](http://uarpp.uark.edu/personnel.htm)
• [http://entoplp.okstate.edu/sprec/index.htm](http://entoplp.okstate.edu/sprec/index.htm)
Acknowledgements


- Thanks to The Andersons LLC Delphi facility, in particular, Mr. Bob Marlow for their collaboration over the years in conducting the CO$_2$ early detection study.
Thank You!
Questions?
Klein E. Ileleji, Ph.D.
Associate Professor & Extension Engineer
Agricultural & Biological Engineering Department
Purdue University
225 S. University Street
West Lafayette, IN 47907-2093
Tel: 765-494-1198
Grain Post-Harvest Extension: