Modeling time, aeration, and loading cycle effects on grain packing

Presenter
Mark Casada

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Research Team
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Pack Factor

• Adjustment factor to calculate the mass (M) of grain based on measured volume (V):

\[ M = D_0 \cdot P \cdot V \]

where, \( D_0 \) = initial density (test weight)
\( P \) = average grain packing

note: \( D_0 \cdot P = R \) = pack factor

• Accounts for compaction from overbearing weight of grain above

• Important for accurate grain inventory, government auditing, insurance purposes
Overall Packing Effects

Corn

Wheat

Overall Project Rationale

Very limited information available on the effect of these frequent issues:

- Storage time and aeration
- Partial unloading/loading cycles
- Side discharge
- Large piles
- Secondary grain quality parameters:
  - high dockage
  - high BCFM
  - damage
  - GMO varieties
Project Objectives

• Determine the effect of storage time, up to 12 months, with and without aeration on pack factors of wheat, corn, and barley.

• Determine the effect of bin loading and unloading procedures on packing (partial unloading and refilling and side discharge) using field- and laboratory-scale bins.

• Evaluate the effects of secondary crop quality parameters (high dockage for wheat, high BCFM for corn, and GMO vs. non-GMO varieties) on grain packing by characterizing fundamental compressibility relationship.
**Approach**

- Laboratory measurements of fundamental compressibility relationships.
- Detailed pilot-scale measurements in laboratory.
- Full-scale measurements for validation.
- Refine the science-based model with the new information.
Aeration Effects – Laboratory Study

• Examined how aeration and moisture shrink effect volume
• Three treatments
  • Wet grain with aeration
  • Grain at equilibrium with aeration
  • Grain at equilibrium w/o aeration
• Two crops
  • Corn
  • Soybeans
Aeration Test Conditions

• 6” diameter PVC pipes with H/D=1
• Airflow
  • Exit velocity ~ 44.6 ft./min
  • ~111 cfm/bu
• Corn
  • 20°C / 50% RH (EMC 11.9%wb)
• Soybeans
  • 15.5°C / 55% RH (EMC 9.1% wb)
Wet samples dried from 15.7% to 12.2%
Soybean Aeration

Wet samples dried from 13.3% to 10.6%
• Early field results for corn, soybeans, sorghum, and HRW Wheat
HRW wheat stored for about 20 days with 155.5 hours of aeration
Corn corrugated steel bins with diameter of 7.3 m and eave height of 6.4 m stored for 6 months with 852 hours of aeration.
Decrease in grain height from 0.25% to 1.42% after 6 months, non-aerated bins.
**Observations - Time & Aeration Field Data**

**Corn:** With aeration, grain height decreased by 0.06% to 0.5% after 5 months of storage.

**Soybeans:** With aeration, grain height decreased by 0.06% to 0.21% after 5 months of storage.

**Sorghum:** Without aeration, grain height decreased by 0.04% to 0.08% after 5 months of storage.

**HRW Wheat:** Without aeration, no decrease in grain height for storage up to 4 months.
Partial Unloading – Field Data

• Ethanol Plant, St. Louis, MO
• Steel corrugated flat bottom bin, 80 ft dia., 63 ft eave height
• Measured packing:
  5.32% & 5.34%
• Model calculated:
  4.9% and 5.0%
Damage, GMO, & Compressibility

- Factors that could influence the behavior of grain in compression were examined utilizing confined uniaxial compression tests.
- Factors examined were:
  - Mold damaged corn
  - Insect damaged corn
  - Soybeans with GMO traits
Compressibility Test Set Up
Mold Damage

• Pioneer 33d49 from KS
• Test weight
  • Before- 723 kg/m³
  • After- 699 kg/m³
• MC
  • Before-9.6%
  • After-10.3%
• 41% mold damaged
• 6.5% broken
• 1.4% insect damaged
Mold Damage - Compressibility Results

![Graph showing density vs. overburden pressure for mold damaged and original samples.](image-url)
Insect Damage

- Croplan 5757 VT3 from KS
- Test weight
  - Before-795 kg/m³
  - After-723 kg/m³
- MC
  - Before-11.2%
  - After-10.8%
- 17.8% ± 4% Insect damage
Insect Damage - Compressibility Results

![Graphs showing the effect of overburden pressure on density and density increase for insect damage compared to original samples.]
## Soybeans

- Two comparisons
  - KS3406RR GMO 2015 OT vs KS4313N Non GMO 2015 OT
  - KS c. A GMO 2015 OT vs KS c. A Non GMO 2015 OT
- Nominal MC’s - 10% and 14% wb
- Less than 3 kg/m³ difference in test weight between GMO and Non GMO samples

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Thank You !
Acknowledgements

• USDA and Kansas Ag Experiment Station
• Dennis Tilley, Kevin Hamm, and Howell Gonzales
• Farm Service Agency, Wheat Commission, Farmers, and all the Elevator Cooperators
Thompson et al. (1987)

- Crop varieties effect (under equal levels of overburden pressure):
  - SRW wheat and rough rice underwent large amounts of packing than Corn

- Variation in the values of $\mu$ (friction coef.) has greater effect on the packing factor than $k$ (lateral to vertical pressure) ($\sim$ double)

Thompson et al. (1991)

- Doubling the grain height
  - Avg. increase in packing factor of 1.2% for wheat

- Doubling the grain diameter
  - Avg. increase in packing factor of 0.23% for wheat

- Increase in moisture content from 10% to 16% db (material became more compressible, increase in packing)
  - Avg. increase in packing factor of $\sim$0.4 to 0.90% for wheat
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* All are steel corrugated bins; maximum storage period up to 6 months
Laboratory Compressibility Tester
HRW wheat corrugated steel bins with diameter of 5.6 m and eave height of 4.0 m stored for about 20 days with 155.5 hours of aeration.
Corn corrugated steel bins with diameter of 7.3 m and eave height of 6.4 m stored for 6 months with 852 hours of aeration.

Barley corrugated steel bins with diameter of 27 m and eave height of 20 m stored for up to a year (non-aerated).

Decrease in grain height by 0.25% to 1.42% was seen between 5 to 7 months of storage.