Challenges in On-farm Drying and Storage of Soybean for Seed in Modern Bin Systems

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Introduction

- Commercial practice allows seed to dry in field to 13% MC (w.b).
- Seed subjected to fluctuating levels of moisture deteriorate fast
- Fungi present on stored seed are a major cause of quality losses
Modern In-bin Drying and Storage System and Features

Sensor node on cable

Communication System
- Monitors
  - Temperature Sensing
  - Moisture Sensing
  - Insect Detection
  - Headspace RH/T
  - Pressure
- Communicates to the PC by wired and/or wireless connection
- High limit, rate-of-rise and system status alarms
  - On-screen
  - On-site (audible or visual)
  - Text messaging
  - E-mail
- Interface
  - On-site
  - By internet

Weather Station

Fan Control System

<table>
<thead>
<tr>
<th>Bin Diameter</th>
<th>&lt;24'</th>
<th>24'</th>
<th>36'</th>
<th>42'</th>
<th>48'</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coverage with OPI recommended cables</td>
<td>90%</td>
<td>99%</td>
<td>80%</td>
<td>86%</td>
<td>88%</td>
</tr>
<tr>
<td>Coverage with One center cable only</td>
<td>90%</td>
<td>69%</td>
<td>31%</td>
<td>23%</td>
<td>17%</td>
</tr>
</tbody>
</table>
User-friendly interface
EMC Prediction challenges

Desorption/rehydration

Desorption/drying
## Common EMC Isotherm Prediction Models

<table>
<thead>
<tr>
<th>Name of model</th>
<th>Equilibrium moisture content model</th>
<th>Water activity / ERH model</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modified Henderson</td>
<td>[ MC \approx \left(\frac{-\ln(1-a_w)}{A(T+B)}\right)^{1/c} ]</td>
<td>[ a_w \approx 1 - \exp[-A(T + B)M^C] ]</td>
</tr>
<tr>
<td>Modified Chung-Pfost</td>
<td>[ MC \approx \frac{-1}{c} \ln \left[ -\frac{(T+B)}{A} \ln(a_w) \right] ]</td>
<td>[ a_w \approx \exp\left[\frac{-A}{(T+B)} \exp(-CM)\right] ]</td>
</tr>
<tr>
<td>Modified Halsey</td>
<td>[ MC \approx \left[ \frac{-\ln(a_w)}{\exp(A+BT)} \right]^{-1/c} ]</td>
<td>[ a_w \approx \exp[-\exp(A + BT)M^{-C}] ]</td>
</tr>
<tr>
<td>Modified Oswin</td>
<td>[ MC \approx (A + BT)\left[ \frac{a_w}{1-a_w} \right]^{1/c} ]</td>
<td>[ a_w \approx \frac{1}{\left[ \frac{(A+BT)}{M} \right]^C + 1} ]</td>
</tr>
<tr>
<td>Modified GAB</td>
<td>[ MC \approx \frac{AB \left( \frac{C}{T} \right)^C a_w}{(1-Ba_w+\left( \frac{C}{T} \right)Ba_w)(1-Ba_w)} ]</td>
<td>[ a_w \approx \frac{2+C(A-1)[\left( \frac{2+C(A-1)}{T(M-1)} \right)^2 - 4(1-\frac{C}{T})^{1/2}}{2B(1-\frac{C}{T})} ]</td>
</tr>
</tbody>
</table>
Bottom-line

• **Effective fan control requires accurate EMC isotherms**

• **Rate at which the drying front moves and other characteristics including hydration and dehydrations will impact seed germination and vigor**
“.... to fine-tune EMC prediction models for accurate fan control during natural air in-bin drying and storage;

.........to maintain soybean seed quality, specifically seed germination rate and vigor”.

Research Objective
Conventional cultivars
Functional soybeans
Growing locality

Temperature
35°C
25°C
15°C etc.

Desorption
90%
70%
50%
30%
10%

Adsorption
10%
30%
50%
70%
90%

Relative Humidity

EMC isotherm Determination

VSA - New and rapid method for accurate grain EMC determination
Drying and Simulations

Finite Difference Model (FDM)

Program User Interface
FDM User interface
FDM User interface
## Simulation Scheme for NA Drying and Storage

<table>
<thead>
<tr>
<th>Simulation year</th>
<th>Location</th>
<th>Strategy</th>
<th>Air flowrate (m³/min·t⁻¹)</th>
<th>Initial moisture content (%w.b.)</th>
<th>Drying-start date</th>
</tr>
</thead>
<tbody>
<tr>
<td>1995 to 2014</td>
<td>Stuttgart, AR</td>
<td>EMC-controlled NA</td>
<td>1.04 (1 cfm bu⁻¹)</td>
<td>16</td>
<td>8/15</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>2.08 (2 cfm bu⁻¹)</td>
<td></td>
<td>9/15</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>3.12 (3 cfm bu⁻¹)</td>
<td></td>
<td>10/15</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>4.16 (4 cfm bu⁻¹)</td>
<td></td>
<td>11/15</td>
</tr>
</tbody>
</table>
Simulation Termination Conditions

- Target MC: 13% w.b.

- Ending condition:
  - 90 day from drying start date Or
  - The top layer <14% w.b.

- Control strategy:
  - MC lower limit base (function of target bin MC)
  - Dynamic MC_LowLimit
  - Dynamic MC window: \((\text{Average bin MC} - \text{Target bin})/2\)
RESULTS
### Stuttgart AR (EMC- Controlled NA Drying of Soybean, Harvest MC =16%)

**Air Flowrate, m³-min⁻¹ (cfm bu⁻¹)**

<table>
<thead>
<tr>
<th>Air Flowrate</th>
<th>Drying Duration (days)</th>
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<tr>
<td>1.04 (1)</td>
<td></td>
</tr>
<tr>
<td>2.08 (2)</td>
<td></td>
</tr>
<tr>
<td>3.12 (3)</td>
<td></td>
</tr>
<tr>
<td>4.16 (4)</td>
<td></td>
</tr>
</tbody>
</table>

#### Drying-start Date
- **Aug-15**
- **Sept-15**
- **Oct-15**
- **Nov-15**
Stuttgart AR (EMC- Controlled NA Drying of Soybean, Harvest MC = 16%)

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<table>
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<tr>
<th>Average Final Moisture Content (%w.b.)</th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>14.0</td>
<td>13.0</td>
<td>12.0</td>
<td>11.0</td>
</tr>
</tbody>
</table>

**Location**
- Stuttgart_AR

**Drying-start Date**
- Aug-15
- Sept-15
- Oct-15
- Nov-15
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<tr>
<th>Drying cost (c/bu)</th>
<th>Stuttgart_AR</th>
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Drying-start Date:
- Aug-15
- Sept-15
- Oct-15
- Nov-15
Germination and Vigor Determination - ISTA standards

Parameter Generation & Control unit for temperature and relative humidity control

Electrical Conductivity determination
Mean Germination % vs. Storage Duration (IMC = 16%; 30 °C)

Soybean MC = 16%; 2015 crop year
Growing location – Fayetteville AR

Soybean Cultivars

- B96
- R08
- R09

Equations:

Y (B96) = 101.7 - 0.9223*X
RMSE (B96): 3.68
R² (B96): 0.97

Y (R08) = 100.9 - 0.8603*X
RMSE (R08): 3.38
R² (R08): 0.97

Y (R09) = 97.51 - 0.7366*X
RMSE (R09): 3.85
R² (R09): 0.94
Mean Electrical Conductivity % vs. Storage Duration

Soybean MC = 16%; 2015 crop year
Growing location – Fayetteville AR

Soybean Cultivars

Electrical Conductivity

Storage Duration (days)
Concluding remarks

• Drying start date may significantly affect effectiveness of EMC-controlled drying of soybeans for seed
  – *Example (Stuttgart AR): at lower air flow rates the variation in drying duration is more pronounced with respect to drying-start date*

• Generally, drying cost lowest at lower air flow rates but the associated long drying durations may jeopardize seed germination rate
  – *Do not compromise cost for seed germination rate*
Concluding remarks

• Late harvesting in fall (Nov. 15 for Stuttgart AR location) resulted in minimum percent over drying of the soybeans

• Steady reduction of seed germination potential (%) resulted when the seed remained at elevated MC for prolonged duration
  – About 10 percentage points reduction in germination potential (%) resulted for seeds kept at 16% MC for 10 days; large increase of seed EC reflecting loss of seed integrity was also noted
Acknowledgments

- Arkansas Soybean Research and Promotion Board
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- Numerous soybean producers across AR
Thanks