Drying and Storage Properties of Selected Specialty Grains

Samuel G. McNeill, Associate Extension Professor
Biosystems and Agricultural Engineering, University of Kentucky, Princeton, KY 42445-0469

Michael D. Montross, Associate Professor
Biosystems and Agricultural Engineering, University of Kentucky, Lexington, KY 40546-0276

Written for presentation at the
2005 ASAE Annual International Meeting
Sponsored by ASAE
Tampa Convention Center
Tampa, Florida
17 - 20 July 2005

Abstract. Drying experiments were conducted to simulate two typical types of on-farm systems: high-temperature bin dryers and high temperature automatic batch or continuous flow units. Temperature and relative humidity levels chosen were 60 C and 10%, and 80 C and 6%, respectively. Specialty grains selected were high-oil corn, triple-null soybean, and soft white winter wheat because they have been grown on a limited basis to explore alternative crop opportunities that may yield higher profits because of potential food-grade markets. Drying parameters from the Page equation were determined from the experimental data and compared with values for conventional grains (yellow corn, soybean, and soft red winter wheat) listed in the ASAE Standards. Results showed that drying parameters for specialty grains were both higher and lower for high-oil corn, soybean, and soft white wheat, depending on test conditions.

Storage conditions evaluated for the same products included temperatures of 10, 25, and 40 C and relative humidities between 40 and 80%. The dew-point method of moisture equilibration was selected to determine grain EMC. Measured values were compared to values generated from prediction equations in the ASAE Standards for conventional grains and found to vary by less than a point of moisture (% wb) for some conditions, yet by more than 3 points of moisture at high temperatures and relative humidity levels.

Results suggest that further study is needed to investigate the differences observed in these tests.

Keywords. High-oil corn, soybean, soft wheat, EMC.
Introduction

Many stakeholders in the grain trade have suggested that markets should shift from a traditional “grade” based system to a new “traits” based system. The grade based system measures physical properties of a product to set the price, whereas both physical and intrinsic properties of a product are used to set the price with the traits based system. This change reflects the fact that buyers recognize the value of components in grain products, for example, starch and oil in corn, protein in wheat, and oil and protein in soybeans.

Specialty grains have received much attention by Kentucky farmers recently because they have been offered premiums of 5 to 50 cents per bushel above prices offered for traditionally grown No.2 yellow corn or No.1 soybeans. For example, farmers have received a 20 cent per bushel premium for high oil corn with a minimum oil content of 6.5% (dry moisture basis), and an additional cent for each 0.1 % point of oil above the base level up to 8.0% (or a maximum premium of 35 cents per bushel). Of course, farmers must always consider the trade-offs between yield potential and any additional handling, drying or storage costs of new crop hybrids before they can fully evaluate an economic comparison between new crops and historically grown grains.

Equilibrium moisture content (EMC) and equilibrium relative humidity (ERH) data are essential for the design and operation of drying and storage processes. Yet little data exists for specialty grains, which has been shown to be significantly different than traditional/historical crops. A recent study compared the relative storability of high-oil corn to conventional corn where CO₂ production was used as an indicator of dry matter loss (Ileleji, et al., 2003). Moreover, a hysteresis phenomenon has often been found in grain that produces a difference between drying/desorption and wetting/adsorption isotherms. The primary motivation of this work involves desorption which is important in drying and storage applications.

This study was initiated to determine the best drying and storage conditions for specialty grains to help farmers, elevator operators, and grain storage/seed warehouse managers protect the seed quality and high value traits of these products. Ultimately, new recommendations may be needed to properly dry and store specialty grains that have different chemical composition than commonly grown varieties.

Objectives

1. Measure the equilibrium moisture content of the same specialty varieties of high oil corn, triple-null soybeans, soft white winter wheat (SWWW), and traditional yellow corn, soybean, and soft red winter wheat (SRWW) to determine if there are differences between specialty grains and popular varieties.

2. Conduct drying tests of specialty corn, soybean and white wheat varieties and historically grown/traditional yellow corn, soybean and red wheat varieties to determine respective drying rates.

3. Use existing mathematical models to describe the drying behavior and equilibrium moisture content level of these selected specialty crops and compare equation parameters between like products.
Background

Storage Tests

A dynamic measuring system has been used to determine the EMC relationships of agricultural products by circulating a relatively small quantity of air through a relatively large product sample. Flood and White (1984) used a sample size of 600 g and an airflow rate of 700 mL/min to determine the EMC of popcorn. The sample temperature and dew point temperature of the circulating air establishes the ERH. Due to the small volume of air being circulated through the sample no moisture change occurs during the equilibration process. The dew point temperature of the air was measured until there was no change. The moisture content of the grain sample was determined using an oven method. A similar technique was used to determine the EMC of various specialty grains in this study.

Drying Tests

Drying and storage characteristics and seed deterioration rates of most newly developed specialty grains are rarely reported and may be substantially different than the varieties that are historically grown. For example, a drying study at Purdue University showed differences up to 15% in the drying time between two high oil corn varieties (Maier and Watkins, 2001), and although stress cracks were observed for both products, equilibrium moisture content levels were not determined.

Methods

Storage Tests

- Grain samples fully exposed in constant temperature and relative humidity environment
- Recorded weight changes during several days of exposure
- Dry matter determined by oven-drying method (ASAE S352.2, 2000)
- Repeated tests for different relative humidity at constant temperature (40 to 80%)
- Repeated tests for different temperatures (10, 25 and 40 C)
- Compared average experimental EMC values to the average generated published equations (ASAE D245.5, 2000)— the modified Halsey equation for soybean and the average of the modified Chung-Pfost and modified Henderson equations for corn and wheat

Drying Tests

- Thin-layer, fully exposed drying tests in controlled environment for 3 to 8 hours
- Recorded weight changes during drying
- Dry matter determined by oven-drying method (ASAE S352.2, 2000)
- Repeated tests for different temperatures (65 and 80 C)
Generated parameters from the Page equation (ASAE S448, 2000) to describe drying behavior

**Results**

**Storage Tests**

- Absolute differences between observed and published EMC values for corn ranged between 0.5 to 2.7, 0.1 to 1.8, and 0.1 to 1.8 % wb, for 10, 25 and 40 C, respectively
- Differences between average EMC values for high-oil corn and conventional corn were less than those for published values, especially at 10 and 25 C
- Absolute differences between observed and published EMC values for soybean ranged between 0.2 to 2.8, 0.7 to 2.8, and 0.0 to 0.4 % wb, for 10, 25 and 40 C, respectively
- Differences between average EMC values for specialty soybean were less than those for published values, especially at 10 and 25 C
- Absolute differences between observed and published EMC values for wheat ranged between 1.4 to 4.0, 0.1 to 3.1, and 0.1 to 3.1 % wb, for 10, 25 and 40 C, respectively
- Differences between average EMC values for SRW wheat and SWW wheat were less than those for published values, especially at 10 and 25 C

**Drying Tests**

- The Page equation with newly generated regression parameters (k and n) adequately described the drying behavior of all products tested (Table 1 and Figs. 4-6)
- Regression equation parameters for high-oil corn at 80 C were similar to those found for conventional corn but different than those found in the ASAE Standard (Table 1)
- Regression equation parameters for specialty soybean were similar to those in the ASAE Standard for 65 and 80 C
- Regression equation parameters for SR wheat and SW wheat were very similar but lower than the corresponding values in the ASAE Standard for wheat at 65 C
- The Page equation with k- and n- values from the ASAE Standards did not satisfactorily describe the drying behavior of the products tested under these conditions
Conclusion

Storage Tests

- Average observed EMC values for specialty corn, soybean and wheat were within practical limits for many portable moisture meters (0.5% wb) when compared to published values, especially at 40 C.
- Absolute differences between observed and published EMC values for corn, soybean and wheat ranged between 0.1 to 2.7, 0.0 to 2.8, and 0.1 to 4.0 % wb, respectively, for all temperatures.
- Differences in observed and published EMC values were generally higher at lower temperatures and higher humidity conditions for all products.
- Further study is needed to address the differences found between measured EMC values and those predicted by the equations for corn, soybean and wheat given in the ASAE Standards.

Drying Tests

- Further study is needed to investigate the differences found between published drying parameters for the Page equation and those found by regression for the products tested and environmental conditions used in this study.

Acknowledgements

This study was made possible by a grant from the University of Kentucky New Crop Opportunities Center. The authors deeply appreciate the capable assistance of Wei Chen, who assisted with data collection during the drying and equilibrium moisture conditioning tests.

References


Table 1. Summary of drying test conditions, regressed and published parameters for Page equation \((MR = \exp(-k \cdot t^n))\), and sum of squares for estimates.

<table>
<thead>
<tr>
<th>Material</th>
<th>Variety</th>
<th>Temp °C</th>
<th>RH %</th>
<th>Average MO %db</th>
<th>EMC %db</th>
<th>Time, h</th>
<th>Regression-Page</th>
<th>Sum of Squares</th>
<th>ASAE %db</th>
<th>Sum of Squares</th>
<th>M, %db</th>
<th>MR</th>
<th>k</th>
<th>n</th>
<th>MR</th>
<th>%db</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corn</td>
<td>Wyffels 7355</td>
<td>80</td>
<td>6</td>
<td>20.5</td>
<td>1.27</td>
<td>3.35</td>
<td>0.388 0.574</td>
<td>1.04 0.0004</td>
<td>0.613</td>
<td>0.305 0.199</td>
<td>79.2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Corn</td>
<td>Pioneer 2563</td>
<td>80</td>
<td>6</td>
<td>23.1</td>
<td>1.27</td>
<td>4.57</td>
<td>0.477 0.565</td>
<td>1.61 0.0065</td>
<td>0.613</td>
<td>0.326 0.066</td>
<td>25.6</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Corn</td>
<td>Pfister 2550-19</td>
<td>80</td>
<td>6</td>
<td>20.9</td>
<td>1.27</td>
<td>3.25</td>
<td>0.434 0.554</td>
<td>2.60 0.0015</td>
<td>0.613</td>
<td>0.308 0.138</td>
<td>54.4</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Soybean</td>
<td>IA 2025</td>
<td>65</td>
<td>10</td>
<td>17.2</td>
<td>3.40</td>
<td>7.39</td>
<td>0.613 0.649</td>
<td>1.96 0.0102</td>
<td>0.502</td>
<td>0.556 0.275</td>
<td>1.96</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Soybean</td>
<td>IA 2042</td>
<td>65</td>
<td>10</td>
<td>13.1</td>
<td>3.40</td>
<td>7.14</td>
<td>0.587 0.676</td>
<td>2.96 0.0370</td>
<td>0.502</td>
<td>0.556 0.323</td>
<td>30.4</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Soybean</td>
<td>IA 2025</td>
<td>80</td>
<td>6</td>
<td>18.1</td>
<td>3.20</td>
<td>3.63</td>
<td>0.750 0.670</td>
<td>0.30 0.0014</td>
<td>0.665</td>
<td>0.592 0.048</td>
<td>10.7</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Soybean</td>
<td>IA 2042</td>
<td>80</td>
<td>6</td>
<td>18.7</td>
<td>3.20</td>
<td>7.63</td>
<td>0.415 0.612</td>
<td>4.71 0.0223</td>
<td>0.665</td>
<td>0.592 5.983</td>
<td>152.8</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SRW</td>
<td>Pioneer 2552</td>
<td>65</td>
<td>10</td>
<td>17.2</td>
<td>2.00</td>
<td>7.69</td>
<td>0.859 0.477</td>
<td>1.93 0.0054</td>
<td>2.05</td>
<td>1.00 1.010</td>
<td>235.3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SRW</td>
<td>Pioneer 25W60</td>
<td>65</td>
<td>10</td>
<td>20.9</td>
<td>2.00</td>
<td>7.36</td>
<td>0.900 0.500</td>
<td>0.74 0.0028</td>
<td>2.05</td>
<td>1.00 0.864</td>
<td>307.2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>