PS8-9 – 6242

Study of the performance of natural air/low temperature in-bin drying of different corn types using simulation

R. Bartosik\textsuperscript{1,*}, D.E. Maier\textsuperscript{2}

Abstract

The use of simulation for studying natural air/low temperature (NA/LT) in-bin drying systems is a common practice. This tool was used in the past to determine, for instance, the most convenient airflow rate, the most convenient fan and burner control strategy according to the weather conditions, and the maximum allowable initial moisture content. However, the effect of different corn types on drying performance was never studied before. Bartosik (2005) studied the adsorption and desorption EMC relationships of three corn types (yellow dent, white and waxy) and concluded that they were significantly different. The specific EMC relationships of these three different corn types were programmed into a NA/LT in-bin drying simulation tool (PHAST-FDM). The PHAST-FDM was validated with the white and yellow dent corn types, and the in-bin drying of the three corn types was studied in four locations in the Midwestern Corn Belt (Evansville, Indiana; Indianapolis, Indiana; Des Moines, Iowa; North Platte, Nebraska). It was found that the Drying Cost for the yellow dent corn type was the lowest for all locations, followed by the white corn type and last by the waxy corn type. The difference in the Drying Cost was more significant in the northern regions (North Platte, Nebraska), where the Drying Cost for the white corn type was 17.0 % more expensive than the Drying Cost for the yellow dent corn type, while the waxy corn type was 52.2 % more expensive. The higher Drying Cost predicted for the white and waxy corn types was related to the longer drying time required for these two corn types when compared to the drying time required for the yellow dent corn type. Although it was a common knowledge among farmers that different corn types had different drying time (and drying cost), this information was never quantified before.

Key words: Yellow Dent Corn, Waxy Corn; White Corn, Simulation; In-Bin Drying; Drying Cost.

Introduction

Natural air/low temperature (NA/LT) drying systems are characterized by the in-bin drying of grains with relatively low airflow rates (most typically from 1 to 2 m\textsuperscript{3} min\textsuperscript{-1} t\textsuperscript{-1}) and natural air or air heated up to 7 °C over the ambient temperature. The performance of NA/LT in-bin drying systems is weather-dependant, which makes it difficult to extrapolate results from a field-test carried out in one location to another location. Additionally, due to the year to year weather variability it is difficult to formulate general conclusions about the behavior of a particular in-bin drying strategy based on a single year test.

\textsuperscript{1} EEA INTA Balcarce, Ruta 226 km 73,5 (7620), Balcarce, Provincia de Buenos Aires, Republica Argentina. e-mail: rbartosik@balcarce.inta.gov.ar
\textsuperscript{2} Agricultural and Biological Engineering Department, Purdue University, 225 South University street, West Lafayette, 47906 IN, Indiana, USA. e-mail: maier@purdue.edu
\* Corresponding author
This situation makes it virtually impossible to conduct a comprehensive evaluation of NA/LT in-bin drying strategies based on field tests. Computer simulation based on historical weather data has been extensively used in the past to evaluate the performance of NA/LT in-bin drying systems. Some of the advantages of using computer-based simulation models are the low cost involved, the availability of historical weather information for many different geographical regions, and the speed of the process.

Purdue University has a long history of successful application of simulation modeling to study in-bin drying and conditioning processes with the Post-Harvest Aeration and Storage Simulation Tool – Finite Difference Method (PHAST-FDM) (Bartosik and Maier, 2006; Bartosik and Maier, 2004; Montross and Maier, 2000; and Zink, 1998). Bartosik and Maier (2005) implemented and evaluated a new fan and burner control strategy for NA/LT in-bin drying, named Variable Heat (VH). The VH strategy was based on an ambient air selection and conditioning mode. Field tests showed that the VH strategy successfully avoided the overdrying of the grain bottom layers. Bartosik and Maier (2004) simulated the performance of three in-bin drying strategies (VH, continuous constant heat (CCH) and CNA strategies) in four Midwestern Corn Belt locations. They found that, based on the average drying cost of the 29 years analyzed, the VH strategy was the best choice for each location investigated. However, for most location and harvest date combinations, there were a number of years in which the lowest drying cost was observed for the CNA and CCH strategies.

Bartosik (2005) incorporated an equilibrium drying model into a new strategy called self-adapting variable heat (SAVH) strategy. This new strategy was able to recognize the weather pattern during the drying season and self-adapt its low moisture content limit accordingly. The SAVH strategy was evaluated in a series of field tests (Bartosik, 2005). The PHAST-FDM model was modified to better predict moisture content changes during in-bin drying. The main modifications were summarized by Bartosik (2005). The new SAVH strategy was incorporated into the PHAST-FDM model and validated with experimental data.

The objective of this research was to compare the drying characteristics of different corn types (yellow dent, white and waxy) in different locations in the Midwestern Corn Belt.

Methodology

The drying performance of three different corn types (yellow dent, white and waxy) was evaluated using the PHAST-FDM simulation tool and 40 years of historical weather data for four locations in the Midwestern Corn Belt: North Platte (Region A), Des Moines (Region B), Indianapolis (Region C) and Evansville (Region D). The PHAST-FDM simulation tool was previously updated with the EMC parameter values for yellow dent, white, and waxy corn obtained by Bartosik (2005). A typical farm bin of 12 m (39 ft) diameter and 7 m (23 ft) depth that held 541.9 tonnes of corn at 20% MC (21,676 bu) level filled was selected. For this grain depth, corn type and airflow rate, the fan pre-warming was estimated to be 0.97°C, and the power required by the fan electrical motor was 17.4 kWh. The evaluation was made by comparing the Drying Cost of the white and waxy corn type with the Drying Cost of the yellow dent type for each one of the regions. The initial MC for the simulation was 20%, and the airflow rate was 1.11 m³/min·t⁻¹. The harvest date for each location was November 1, October 15, October 1 and September 15 for North Platte (Nebraska), Des Moines (Iowa), Indianapolis (Indiana) and Evansville (Indiana), respectively.

The Drying Cost included the energy cost (fan and burner) and the shrink cost (overdrying and DML). Thus, this single parameter was considered to be sufficient to quantify the energy consumption and, in an indirect way, the quality of the grain at the end of the drying process. Traditionally it was assumed that a DML of 0.5 % or higher for yellow dent corn corresponded to a change from grade number 1 of the U.S. grain commercialization.
standard to grade number 2. However, several researchers, including Wilcke et al. (1993) showed that the 0.5 % of DML was arbitrary and a change in the U.S. grain grade for yellow dent corn could be observed for lower or higher than 0.5 % DML values. Thus, for this research the DML was considered in the cost analysis only as a physical loss of weight. The electricity price was 0.09 $/kWh, the propane price was 0.5 $/gallon, and the corn price was 93.6 $/t (2.34/bu). The drying cost did not include any fixed cost component (i.e., ownership cost, initial investment, interest rate, etc). A detailed explanation of the computation of the drying cost can be found in Bartosik and Maier (2004).

Results and discussion

Bartosik (2005) studied the adsorption and desorption EMC relationships of three different corn types (yellow dent, white and waxy) and concluded that they were significantly different. When the corn type specific EMC relationship was programmed into PHAST-FDM for NA/LT in-bin drying simulation, the different EMC relationships of these three corn types resulted in different NA/LT in-bin drying performances. Table 1 shows that for the four locations investigated, the drying time (hours required to complete drying) was lower for the yellow dent corn type, followed by the white corn type, and then by the waxy corn type. Additionally, the drying performance of the three corn types was affected differently by the weather conditions during the drying season of the location. The average drying time (Avg. Drying Hours column) for the warmest location considered (Evansville, Indiana) increased from 1,127 hours for the yellow dent corn type to 1,301 (15 %) and 1,443 (28 %) hours for the white and waxy corn types, respectively. On the other hand, the average drying time for the coldest location considered (North Platte, Nebraska) increased from 1,521 hours for the yellow dent corn type to 1,913 (26 %) and 2,249 (48 %) hours for the white and waxy corn types, respectively.

The longer time required to dry white and waxy corn types resulted in more fan and burner run-hours compared to the fan and burner run-hours required to complete drying for the yellow dent corn type. However, the increase of the fan run-hours was higher than the increase of the burner run-hours. In addition, the increase of both fan and burner run-hours was more substantial for the colder regions than for the warmer regions. For the warmer location of Evansville (Indiana), 81 (9 %) and 210 (22 %) extra fan run-hours were required to dry white and waxy corn types, respectively. However, only 2 (1 %) and 58 (34 %) extra burner run-hours were required for the white and waxy corn types, respectively. For the colder location of North Platte (Nebraska), 305 (22 %) and 555 (35 %) extra fan run-hours were required to dry the white and waxy corn types, respectively. However, 51 (11 %) extra burner run-hours were required for the white corn and 430 (89 %) for the waxy corn type.

The additional fan and burner run-hours required to dry the white and waxy corn types compared versus the fan and burner run-hours required to dry the yellow dent corn type resulted in higher drying cost for the first two corn types. Table 1 shows the expected Drying Cost for drying yellow dent, white and waxy corn types in North Platte, Des Moines, Indianapolis and Evansville, corresponding to the four previously identified Regions A, B, C and D, respectively. The Drying Cost of the white corn type was always more expensive than the Drying Cost of yellow dent corn type. In addition, the Drying Cost for the waxy corn type was always higher than the Drying Cost for the yellow dent corn type. The Drying Cost of the different corn types was affected by the weather conditions during the drying season of the location. In Region A (North Platte, Nebraska), the Drying Cost for the white corn type was 17.0 % more expensive (1.09 $/t) than for the yellow dent corn type, while the Drying Cost for the waxy corn type was 52.2 % more expensive, or 3.33 $/t. The difference in the Drying Cost among corn types was lower for the warmer regions. For Des Moines (Region B),
the Drying Cost for the white and waxy corn types were 16.3% (0.82 $/t) and 48.9% (2.46 $/t) more expensive than for the yellow dent corn type, respectively. For Indianapolis (Region C), the Drying Cost for the white and waxy corn types were 5.5% (0.25 $/t) and 31.6% (1.45 $/t) more expensive than for the yellow dent corn type, respectively. Finally, for the warmest location (Evansville, Region D) the Drying Cost for the white and waxy corn types were 3.1% (0.13 $/t) and 19.8% (0.86 $/t) more expensive than for the yellow dent corn type, respectively.

These simulations were carried out using the EMC parameters determined for corn samples of one specific hybrid, or at the most a mixture of two hybrids of the same type, of each one of the

<table>
<thead>
<tr>
<th>Location</th>
<th>Avg. cost $/t</th>
<th>Avg. drying hours</th>
<th>Avg. fan hours (% fan runtime)</th>
<th>Avg. burner hours (% burner runtime)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Corn Type</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>White Corn Type</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>North Platte</td>
<td>6.29</td>
<td>1,913</td>
<td>(1,461-2,309)</td>
<td>1,714 (90)</td>
</tr>
<tr>
<td>Des Moines</td>
<td>4.94</td>
<td>1,478</td>
<td>(1,116-2,454)</td>
<td>1,299 (88)</td>
</tr>
<tr>
<td>Indianapolis</td>
<td>4.37</td>
<td>1,308</td>
<td>(1,092-1,477)</td>
<td>1,132 (87)</td>
</tr>
<tr>
<td>Evansville</td>
<td>4.06</td>
<td>1,301</td>
<td>(982-1,785)</td>
<td>1,024 (80)</td>
</tr>
<tr>
<td><strong>Waxy Corn Type</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>North Platte</td>
<td>8.03</td>
<td>2,249</td>
<td>(1,687-2,816)</td>
<td>1,964 (88)</td>
</tr>
<tr>
<td>Des Moines</td>
<td>6.25</td>
<td>1,722</td>
<td>(1,244-2,763)</td>
<td>1,525 (89)</td>
</tr>
<tr>
<td>Indianapolis</td>
<td>5.29</td>
<td>1,488</td>
<td>(1,248-1,793)</td>
<td>1,293 (87)</td>
</tr>
<tr>
<td>Evansville</td>
<td>4.66</td>
<td>1,443</td>
<td>(1,111-1,891)</td>
<td>1,153 (81)</td>
</tr>
</tbody>
</table>
three corn types investigated (yellow dent, white and waxy). Variation in the behavior due to hybrid characteristics, including drying cost, should be expected between different hybrids of each corn type group. However, in order to estimate the Drying Cost for any white corn hybrid it is recommended to use the Drying Cost obtained for the white corn type, rather than the Drying Cost for the yellow dent corn type. Likewise it is also recommended to use of the Drying Cost of the waxy corn type found in this research for the estimation of the Drying Cost of any waxy corn hybrids.

Conclusions

The Drying Cost for the yellow dent corn type was compared to the Drying Cost for the white and waxy corn types for four different locations. It was found that the Drying Cost for the yellow dent corn type was the lowest for all locations, followed by the white corn type and last by the waxy corn type. The difference in the Drying Cost was more significant in the northern regions (North Platte, Nebraska), where the Drying Cost for the white corn type was 17.0% more expensive than the Drying Cost for the yellow dent corn type, while the waxy corn type was 52.2% more expensive. The higher Drying Cost predicted for the white and waxy corn types was related to the longer drying time required for these two corn types when compared to the drying time required for the yellow dent corn type.

Acknowledgements

The authors thank the financial support of The GSI Group, Assumption, Illinois, through Mr. Gene Wiseman and Mr. Dave Andricks. This project was also supported by the USDA Cooperative State Research Education and Extension Service, special research grant numbers 2003-34328-13535 and 2004-34328-15037.

References


