Silage Density and Dry Matter Loss of Bag and Bunker Silos

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Research Lab, Madison, WI  Research Farm, Prairie du Sac, WI
Silage Density and Dry Matter Loss of Bag and Bunker Silos

- Introduction
- Silo bag study
- Bunker research and education
Leading Alfalfa Hay Production States, 1,000 tons, 2003

- Top 10 States
  - 58 % of U. S.
  - 60 % of Acre
  - 4 states NC
  - 6 states West
  - 5 Lead Dairy
Percent of Total 2003 Alfalfa Production - Haylage

- VT
- NY
- WI
- PA
- MI
- MN
- WV
- WA
Why Density and Losses?

Important to:

• Determine true cost of storage
• Estimate feed inventory
• Determine critical management practices

However, little but sales literature is available
Objectives

Monitor filling and emptying of pressed bag silos to:

- Measure densities and losses
- Determine factors affecting each
Methods

• 3 research farms in area (Arlington, Prairie du Sac, West Madison) have used baggers for several years

• 3 machines: 9 ft. Kelly-Ryan, 8 ft. Ag Bag, 9 ft. Ag Bag (rental)
8 Foot Ag Bag
Filling

- All loads:
  - Weighed
  - Marked on bag and length measured
  - Sampled for moisture
  - Composited samples across loads for particle size, CP, NDF, ash
Emptying

- All silage weighed (both good and spoilt)
- A sample per filling load: moisture and various quality characteristics
<table>
<thead>
<tr>
<th>Bagger</th>
<th>Station</th>
<th>Research</th>
<th>Hay</th>
<th>Corn</th>
</tr>
</thead>
<tbody>
<tr>
<td>8’ Ag Bag</td>
<td>Prairie du Sac</td>
<td>2/5</td>
<td>5/6</td>
<td></td>
</tr>
<tr>
<td>9’ Ag Bag</td>
<td>Arlington</td>
<td>0/4</td>
<td>3/3</td>
<td></td>
</tr>
<tr>
<td>9’ Kelly Ryan</td>
<td>Arlington</td>
<td>4/8</td>
<td>4/8</td>
<td></td>
</tr>
<tr>
<td>9’ Kelly Ryan</td>
<td>W. Madison</td>
<td>3/7</td>
<td>3/6</td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td><strong>9/24</strong></td>
<td></td>
<td><strong>15/23</strong></td>
</tr>
</tbody>
</table>
### Average Hay Crop DM Densities

<table>
<thead>
<tr>
<th>Bagger</th>
<th>Research Station</th>
<th>lbs/ft³</th>
<th>kg/m³</th>
</tr>
</thead>
<tbody>
<tr>
<td>8’ Ag Bag</td>
<td>Prairie du Sac</td>
<td>13.1</td>
<td>210</td>
</tr>
<tr>
<td>9’ Ag Bag</td>
<td>Arlington</td>
<td>13.5</td>
<td>217</td>
</tr>
<tr>
<td>9’ Kelly Ryan</td>
<td></td>
<td>14.2</td>
<td>227</td>
</tr>
<tr>
<td>9’ Kelly Ryan</td>
<td>W. Madison</td>
<td>11.6</td>
<td>186</td>
</tr>
</tbody>
</table>
Dry Matter Densities in Hay Crop Silages

Average slope = 0.19 lbs DM/ft^3 / % DM
Dry Matter Densities in Corn Silages - 2000

Average slope = 0.33 lbs DM/ft^3 / % DM
Dry Matter Densities in Corn Silages - 2000, 2001

Average slope=??
AB & KR may have different slopes
## Average Corn DM Densities

<table>
<thead>
<tr>
<th>Bagger</th>
<th>Station</th>
<th>Processed</th>
<th>lbs/ft^3</th>
<th>kg/m^3</th>
</tr>
</thead>
<tbody>
<tr>
<td>8’ Ag Bag</td>
<td>PDS</td>
<td>Yes</td>
<td>13.3</td>
<td>214</td>
</tr>
<tr>
<td></td>
<td></td>
<td>No</td>
<td>15.4</td>
<td>246</td>
</tr>
<tr>
<td>9’ Ag Bag</td>
<td>Arl</td>
<td>Yes</td>
<td>11.0</td>
<td>176</td>
</tr>
<tr>
<td>9’ K R</td>
<td></td>
<td>Yes</td>
<td>12.2</td>
<td>196</td>
</tr>
<tr>
<td>9’ K R</td>
<td></td>
<td>No</td>
<td>10.4</td>
<td>167</td>
</tr>
<tr>
<td>9’ K R</td>
<td>WM</td>
<td>No</td>
<td>11.1</td>
<td>178</td>
</tr>
</tbody>
</table>
## Average DM Densities (lb/ft³)

<table>
<thead>
<tr>
<th>Bagger</th>
<th>Station</th>
<th>Processed</th>
<th>Hay</th>
<th>Corn</th>
</tr>
</thead>
<tbody>
<tr>
<td>8’ Ag Bag</td>
<td>PDS</td>
<td>Yes</td>
<td>13.3</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>No</td>
<td>13.1</td>
<td>15.4</td>
</tr>
<tr>
<td>9’ Ag Bag</td>
<td>Arl</td>
<td>No/Yes</td>
<td>13.5</td>
<td>11.0</td>
</tr>
<tr>
<td>9’ K R</td>
<td>Yes</td>
<td></td>
<td>12.2</td>
<td></td>
</tr>
<tr>
<td>9’ K R</td>
<td>No</td>
<td></td>
<td>14.1</td>
<td>10.4</td>
</tr>
<tr>
<td>9’ K R</td>
<td>WM</td>
<td>No</td>
<td>11.6</td>
<td>11.1</td>
</tr>
</tbody>
</table>
Density Variation on the Face

37%
42%  71%  94%
72%  83%  100%
Density Variation on the Face

- 64%
- 72%
- 71%
- 94%

- 66%
- 71%
- 98%
- 100%

- 60%
- 72%
- 107%
- 106%

- 67%
- 37%
- 73%
- 106%
Density Variation on the Face

80% 83%
104% 84%
21% 149%
71% 66%
62% 106%
42% 37%
71% 100%
94% 72%
83%
Losses

- **Invisible & Uncollected** = Filling + Removal + Gaseous + Seepage (Not Collected) = Total DM in - Total DM removed

- **Spoilage** = Silage not fed (moldy)

- **Total Loss** = Invisible & Uncollected + Spoilage
### Range of Losses (% DM)
#### 24 Bags

<table>
<thead>
<tr>
<th>Type</th>
<th>Loss Range</th>
<th>Loss Average</th>
<th>Average w/o 25%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inv. &amp; Uncol.</td>
<td>-0.3 to 22.8</td>
<td>9.5</td>
<td>8.7</td>
</tr>
<tr>
<td>Spoilage</td>
<td>0.0 to 25.4</td>
<td>6.9</td>
<td>2.7</td>
</tr>
<tr>
<td>Total</td>
<td>-0.3 to 39.9</td>
<td>16.4</td>
<td>11.4</td>
</tr>
</tbody>
</table>

* 25% loss or more
## Issues With The Worst Six Bags

<table>
<thead>
<tr>
<th>Total % Loss</th>
<th>Spoiled (% Loss)</th>
<th>% DM</th>
<th>When Fed</th>
<th>Removal Rate (in./day)</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>39.9</td>
<td>17.2</td>
<td>40.4</td>
<td>27 June</td>
<td>29</td>
<td>Bag burst</td>
</tr>
<tr>
<td>38.2</td>
<td>25.4</td>
<td>42.3</td>
<td>30 March</td>
<td>23</td>
<td>?</td>
</tr>
<tr>
<td>30.6</td>
<td>21.9</td>
<td>43.7</td>
<td>12 March</td>
<td>Bird damage</td>
<td></td>
</tr>
<tr>
<td>27.1</td>
<td>19.3</td>
<td>35.7</td>
<td>3 July</td>
<td>28</td>
<td>?</td>
</tr>
<tr>
<td>26.9</td>
<td>16.6</td>
<td>48.8</td>
<td>1 May</td>
<td>8</td>
<td>Similar bag</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Total = 11%</td>
<td></td>
</tr>
<tr>
<td>25.9</td>
<td>15.7</td>
<td>48.7</td>
<td>20 Aug</td>
<td>53</td>
<td>?</td>
</tr>
</tbody>
</table>
Spoilage Losses vs. DM Content

Dry Matter Content, %

DM Loss, %

Hay
Corn
Spoilage Losses vs. Porosity

DM Loss, %

Porosity, %

Spoilage Losses vs. Porosity

Hay
Corn
Spoilage Losses vs. Emptying Mid-Point Date

DM Loss, %

Oct-00  Feb-01  Jul-01  Dec-01

Bird Damage
Ruptured Bag

Hay
Corn
Invisible & Uncollected Loss vs DM Content

Dry Matter Content, %

DM Loss, %

Hay
Corn
High Spoilage
Invisible & Uncollected Loss vs Feed Out Rate

- Feed Out Rate, in/d
- DM Loss, %

- Hay
- Corn
- High Spoilage
Invisible & Uncollected Loss vs Emptying Mid-Point Date

DM Loss, %

Hay
Corn
High Spoilage

Oct-00 Feb-01 Jul-01 Dec-01
Total Losses vs. Emptying Mid-Point Date

- Ruptured Bag
- Bird Damage

DM Loss, %

Oct-00 Feb-01 Jul-01 Dec-01

Hay
Corn
Summary

• Density in hay crop silage: 12.5 lbs DM/ft³

• Density in corn silage: higher with one bagger, lower in other relative to hay crop

• DM density lower the wetter the hay crop; less certain relationship in corn
Summary

• Average total losses were 16.4%, but 11.4% without 6 bags with major losses (>25%)

• Spoilage in dry (>40% DM), porous silages

• More problems with spoilage in summer

• Evidence that good management necessary for low losses
Management of Bunker Silos

- **Harvest**
  - maturity, moisture, chop length, rapid chop

- **Filling**
  - fill rapidly, pack tight, cover completely and quickly
Management of Bunker Silos

- Harvest
- Filling
- Packing
  - Spread in thin layers
  - Average tractor weight
  - Silage height
  - Packing time/wet ton
## Management of Bunker Silos

Dry matter loss as influenced by silage density.

<table>
<thead>
<tr>
<th>Density (lbs DM/ft³)</th>
<th>DM Loss, 180 days (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>20.2</td>
</tr>
<tr>
<td>14</td>
<td>16.8</td>
</tr>
<tr>
<td>15</td>
<td>15.9</td>
</tr>
<tr>
<td>16</td>
<td>15.1</td>
</tr>
<tr>
<td>18</td>
<td>13.4</td>
</tr>
<tr>
<td>22</td>
<td>10.0</td>
</tr>
</tbody>
</table>

**SOURCE:** Ruppel, K. A. 1992. MS thesis Cornell University, Ithaca, NY
Management of Bunker Silos

- Harvest
- Filling
- Packing
  - Spread in thin layers
  - Average tractor weight
  - Silage height
  - Packing time/wet ton
- Interaction of fill & pack

http://www.uwex.edu/ces/crops/uwforage/storage.htm
Silo Management

• High packing density needed
  – Density & dry matter content → porosity
  – Porosity set rate of air movement into silo
  – Higher the density, greater silo capacity
## Silo Management

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Hay crop silage (87 silos)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Average</td>
</tr>
<tr>
<td>Dry matter (%)</td>
<td>42</td>
</tr>
<tr>
<td>Wet density (lbs/ft³)</td>
<td>37</td>
</tr>
<tr>
<td>Dry density (lbs/ft³)</td>
<td>14.8</td>
</tr>
<tr>
<td>Avg. particle size (in)</td>
<td>0.46</td>
</tr>
</tbody>
</table>

*SD=standard deviation

**SOURCE:** Holmes and Muck, 1999.
## Silo Management

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Average</th>
<th>Range</th>
<th>SD*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dry matter (%)</td>
<td>34</td>
<td>25-46</td>
<td>4.80</td>
</tr>
<tr>
<td>Wet density (lbs/ft³)</td>
<td>43</td>
<td>23-60</td>
<td>8.30</td>
</tr>
<tr>
<td>Dry density (lbs/ft³)</td>
<td>14.5</td>
<td>7.8-23.6</td>
<td>2.90</td>
</tr>
<tr>
<td>Avg. particle size (in)</td>
<td>0.43</td>
<td>0.28-.68</td>
<td>0.08</td>
</tr>
</tbody>
</table>

*SD=standard deviation

**SOURCE:** Holmes and Muck, 1999.
Dry Matter Density Variation

\[
DMD \ (\text{lbs/ft}^3) = (8.5 + PF \times 0.0155) \times (0.818 + 0.0136 \times D)
\]

Where average depth (D) and packing factor (PF) are calculated as:

\[
D = \text{avg. silage depth (ft) = height at wall + height at center) /2}
\]

\[
PF = (W/L) \times N \times DM/C
\]

W = Proportioned average tractor weight (lbs) for all tractors

L = Layer thickness (inches) of the spread but unpacked

N = Number of tractor-packing equivalents, where N = 1 one

DM = Dry matter content (decimal)

C = Crop delivery rate (T AF/hr) to the silo
## Forage Harvester Average Capacity

<table>
<thead>
<tr>
<th>Forage harvester type</th>
<th>Capacity (T AF/hr)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Hay</td>
</tr>
<tr>
<td>Pull, 250 HP</td>
<td>60</td>
</tr>
<tr>
<td>Self-propelled, 450 HP</td>
<td>100</td>
</tr>
</tbody>
</table>

*SOURCE: Shinners, 2001*
# Improving Silage Density*

<table>
<thead>
<tr>
<th>Variables changed</th>
<th>DMD(lbs/ft³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>No change</td>
<td>12.3</td>
</tr>
<tr>
<td>+20,000-lb tractor 50% time</td>
<td>12.7</td>
</tr>
<tr>
<td>+20,000-lb tractor 100% time</td>
<td>13.1</td>
</tr>
<tr>
<td>+5,000 weight to 30,000-lb tractor</td>
<td>13.0</td>
</tr>
<tr>
<td>+5,000 weight to both tractors 100% time</td>
<td>14.1</td>
</tr>
<tr>
<td>Reduce layer thickness 6 to 4-inches</td>
<td>14.5</td>
</tr>
<tr>
<td>Both tractors 100% time &amp; reduce layer to 4</td>
<td>15.6</td>
</tr>
<tr>
<td>+5,000 lb to 30,000-lb &amp; reduce layer to 4</td>
<td>15.5</td>
</tr>
<tr>
<td>+5,000 lb to tractors 100% time &amp; reduce</td>
<td>17.1</td>
</tr>
</tbody>
</table>

*Forage delivery rate increased from 50 to 100 T AF/hr*