Factors Affecting Bunker Silo Density

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Wisconsin Dells

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Why is Density Important?

- DM Loss at Filling
- DM Loss at Ensiling
- DM Loss During Storage
- DM Loss at Feed-Out Face
- Capacity of Storage
## Why is Density Important?

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

* Based on calculations using DM Loss / Day raw data of Ruppel (1992)
Objectives

- Measure densities of corn and hay crop silages in bunker silos
- Survey filling practices for each silo
- Correlate densities with filling practices
Methods

• 19 County Extension agents collected core samples to estimate density

• Farmers surveyed about:
  – Packing tractors: number, weight, number of wheels, number of drive wheels
  – Tires: pressure, condition, fluid-filled
  – Crop delivery rate to silo
  – Harvest, packing times per day
  – Filling practice: technique, initial layer thickness
  – Crop: maturity, theoretical length of cut
Silo Sampling

Core Height

Silage Above Core

Core Holes

Core Height
## Results

### Hay Crop Silages (87 Silos)

<table>
<thead>
<tr>
<th></th>
<th>Average</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dry Matter, %</td>
<td>42</td>
<td>24 - 67</td>
</tr>
<tr>
<td>Wet Density, kg/m³</td>
<td>590</td>
<td>210 - 980</td>
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<tr>
<td>Wet Density, lbs/ft³</td>
<td>36.8</td>
<td>13.1 - 61.2</td>
</tr>
<tr>
<td>Dry Density, kg/m³</td>
<td>237</td>
<td>106 - 434</td>
</tr>
<tr>
<td>Dry Density, lbs/ft³</td>
<td>14.8</td>
<td>6.6 - 27.1</td>
</tr>
<tr>
<td>Avg. Particle Size, mm</td>
<td>11.7</td>
<td>6.9 - 31.2</td>
</tr>
</tbody>
</table>
# Results

## Corn Silages (81 Silos)

<table>
<thead>
<tr>
<th></th>
<th>Average</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dry Matter, %</td>
<td>34</td>
<td>25 - 46</td>
</tr>
<tr>
<td>Wet Density, kg/m³</td>
<td>690</td>
<td>370 - 960</td>
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<tr>
<td>Wet Density, lbs/ft³</td>
<td>43.1</td>
<td>23.1 - 59.9</td>
</tr>
<tr>
<td>Dry Density, kg/m³</td>
<td>232</td>
<td>125 - 378</td>
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<tr>
<td>Dry Density, lbs/ft³</td>
<td>14.5</td>
<td>7.8 - 23.6</td>
</tr>
<tr>
<td>Avg. Particle Size, mm</td>
<td>10.9</td>
<td>7.1 - 17.3</td>
</tr>
</tbody>
</table>
DM Density as Affected by Height of Silage above Core
Densities Adjusted for Height

• Based on Pitt (1983)
  – Tower silo densities with height
  – Used case for the center of the tower (no wall friction)

\[ \gamma(z) = \gamma_o e^{Kg_o g z} \]

\( \gamma_o = \text{wet density at top} \)

\( K = \text{compressibility, } 1.5 \times 10^{-5} \text{ Pa}^{-1} \)

\( z = \text{height from top, } 2.16 \text{ m} \)
Adjusted DM Density in Relation to Height of Silage above Core

![Graph showing adjusted DM density in relation to height of silage above core. The graph plots adjusted density on the y-axis (kg/cu m) against height above core on the x-axis (m). The data points are shown as yellow diamonds. The x-axis is labeled with heights in feet (0, 3.3, 6.6, 9.8, 13.1, 16.4, 19.7, 23.0, 26.2 ft).]
Combined Packing Factor

- Looked at various combinations of factors to find the best explanation of variability in density

\[ PF = \frac{W}{L} \sqrt{T \cdot D} \]

- \( W \) = Avg. Tractor Weight (lbs or Kg)
- \( L \) = Initial Layer Thickness (inches or cm)
- \( T \) = Packing Time,
  - Tractor Hours/Tonne or Ton As Fed
- \( D \) = Dry Matter Content (decimal)
Adjusted Density VS Packing Factor

Adjusted Density, (LBS/ CU FT)

Packing Factor

- Single
- Dual Rear
- All Duals
Predicted Average Silo Densities

- Using the packing factor (PF) and silage height (H), predicted silo density is:

\[ \text{Density} = (PF \times 0.0155 + 8.5) \times (0.818 + 0.0136H) \]

- This will allow farmers to look at means to improve density in their silos.
- Spreadsheet available at:
  
  http://www.uwex.edu/ces/crops/uwforage/storage.htm
Dauphin County, PA  
Bunker Silo Density Study

- 19 Bunkers sampled to estimate density  
- 4 sites across the face at 3 depths  
- Farmers surveyed about:
  - Packing tractors: number, weight, number of wheels, number of drive wheels  
  - Tires: pressure, condition, fluid-filled  
  - Crop delivery rate to silo  
  - Harvest, packing times per day  
  - Filling practice: technique, initial layer thickness  
  - Crop: maturity, theoretical length of cut
<table>
<thead>
<tr>
<th>Farm</th>
<th>Avg Depth (ft)</th>
<th>Deliv. Rate TAF/hr (%)</th>
<th>DM Thickness (in)</th>
<th>Layer Thickness (in)</th>
<th>Tractor Weight (lbs)</th>
<th>Use (%)</th>
<th>Density Measured (lbs DM/cu ft)</th>
<th>Density Estimated (lbs DM/cu ft)</th>
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<td>Avg Depth (ft)</td>
<td>Deliv. Rate TAF/hr (%)</td>
<td>DM Layer Thickness (in)</td>
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<td>Use (%)</td>
<td>Density Measured (lbs DM/cu ft)</td>
<td>Density Estimated (lbs DM/cu ft)</td>
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</tbody>
</table>
Effect of Level and Position on Silage Density

Density (Lbs DM/cu ft)

Position Across Face (Left to Right)

1 2 3 4

Bottom Middle Top
Density vs Depth from Top

\[ y = 0.2781x + 10.637 \]

\[ R^2 = 0.2329 \]
Effect of Bunker Density on Silage Energy

\[ y = 0.0089x + 0.5917 \]

\[ R^2 = 0.3244 \]
## Typical Harvest Rates for Forage Harvesters

<table>
<thead>
<tr>
<th>Crop</th>
<th>Harvest Rate (TAF/hr)*</th>
<th>Towed by 250 hp Tractor</th>
<th>Self-propelled 450 hp Engine</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hay</td>
<td></td>
<td>60</td>
<td>110</td>
</tr>
<tr>
<td>Corn</td>
<td></td>
<td>100</td>
<td>180</td>
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</tbody>
</table>

* Personal communication with Dr. Kevin Shinners, Biological Systems Engineering Dept., UW-Madison
Harvesting Process

CHOP → WAGON/TRUCK → UNLOAD/UNHITCH → TRANSPORT → UNLOAD

RETURN

{ FILL → PACK

50 T/HR

50 T/HR

50 T/HR

Wisconsin TEAM
Forage

Extension
Harvesting Process

120 T/HR

CHOP → WAGON/TRUCK → UNLOAD/UNHITCH → TRANSPORT → UNLOAD

RETURN

FILL → PACK

50 T/HR
Maximum Packing Time with One Packing Tractor

![Graph showing the relationship between harvest rate and packing time. The graph indicates that as the harvest rate increases, the packing time decreases. At a harvest rate of 180 T/hr, the packing time is approximately 0.33 min/T.](image-url)
Conclusions

- Wide variety of densities found in bunker silos
- Important factors:
  - Initial layer thickness
  - Average packing tractor weight
  - Packing time/t as fed
  - Dry matter content
- As harvesting rates go up, farmers will need thin layers and/or multiple, heavy packing tractors to achieve adequate densities
Average Density

Volume Removed = R*W*(PH+WH)/2

Av. Density = Weight Removed/Volume Removed
Example Average Density

Volume Removed = 12”*40”*(15’+10’)/2 = 6,000 cu ft

Av. Density = 90,000 lb DM/6,000 cu ft = 15 lbs DM/cu ft
Harvesting and Storage

Silage Harvesting & Equipment

Estimating the Weight of Forage in a Forage Wagon
by Dan Wiersma, Marshfield Ag Research Station. A "Focus on Forage" fact sheet

Harvest and Storage of High-Quality Corn Silage for Dairy Cows
- .pdf file or PowerPoint PDF
by Dr. Randy Shaver, UW Extension Dairy Scientist

Machinery Designs and Adjustments for Minimized Field Losses
- .pdf file
by Dr. Ron Schuler, UW Extension Ag Engineer

http://www.uwex.edu/ces/crops/teamforage/index.html
Storage Sizing and Management (silage)

**Forage Feedout Losses for Various Storage Systems**
A "Focus on Forage" fact sheet written by Jerry Clark, Chippewa Co. Crops and Soils Educator

**Silage Pile Capacity Calculator** - download as an Excel (*.xls) file
This spreadsheet, developed by Dr. Brian Holmes, is designed to help producers determine the amount of silage in an existing silage pile.

**Silage Pile Dimension Calculator** - download as an Excel (*.xls) file
This spreadsheet, developed by Ken Barnett, Marathon Co. Forage and Farm Mgt Agent, is designed to help producers size silage piles.

**Managing Forage in Bunker Silos**
by Craig Sake, Juneau Co. Agricultural Agent. A "Focus on Forage" fact sheet.

**Management of Bunker Silos and Silage Piles** - .pdf file
by Ken Bolton, Jefferson County Dairy and Livestock Agent, and Dr. Brian Holmes, UW Biological Systems Engineering Dept.

**Preventing Silage Storage Losses** - .pdf file
by Dr. Brian Holmes, UW Biological Systems Engineering Dept. and Dr. Richard Muck, USDA Dairy-Forage Research Center

**Managing Forage in Tower Silos** - .pdf file
by Dr. Brian Holmes, UW Biological Systems Engineering Dept.

**Transferring Silage Between Silos**
by Dr. Randy Shaver, UW Extension Dairy Specialist, and Jim Leverich, Monroe Co. Agricultural Agent.

http://www.uwex.edu/ces/crops/teamforage/index.html
Bunker Silo Cover Alternatives
by Dr. Brian Holmes, UW Biological Systems Engineering Dept.

You Can't Judge a Bunker Silo by Its Cover
by Dr. Brian Holmes, UW Biological Systems Engineering Dept.

Silage Bag Capacity (html) - or available as .pdf file (March, 1999)
by Dr. Brian Holmes, UW Biological Systems Engineering Dept.

Factors Affecting Bunker Silo Densities - .pdf file
by Dr. Brian Holmes, UW Biological Systems Engineering Dept., and Dr. Richard Muck, USDA Dairy-Forage Research Center

Bunker Silo Density Calculator - download as an Excel (*.xls) file
Documentation - download as a *.pdf file (Acrobat Reader needed)
This spreadsheet, developed by Drs. Brian Holmes and Richard Muck is designed to help producers estimate bunker silo densities. Works for both English and Metric units.

Bunker Silo Sizing Spreadsheet - download as an Excel (*.xls) file
Documentation - download as a *.pdf file (Acrobat Reader needed)
This spreadsheet, developed by Dr. Brian Holmes, will help design bunker silos with nearly vertical walls.

http://www.uwex.edu/ces/crops/teamforage/index.html
Run Silage Density Spreadsheet?

YES

NO
PACKING VEHICLE

Heavy Tractor(s) (add weight)
Robust Transmission w Shuttle Shift
Blade or Bucket
Roll Over Protection
w Seat Belts
4-Wheel Drive or Assist
Wheels
Well Lugged
High Tire Pressure
Experienced Operator
PACKING OPERATION - Excludes Oxygen

Progressive Wedge

Thin Layers (6 in)

Uniform Coverage - Two Directions
- Multiple Passes

Continuous

Drive Slowly

Avoid Wheel Slip

One Hour at Beginning and End of Day

Cover Each Night
GO PACK!
Run Silage Density Calculator?

YES  NO
QUESTIONS?