Advances in Silage Preservation

R.E. Muck

US Dairy Forage Research Center

USDA, Agricultural Research Service
Importance of Silage

NASS Estimates Are Low

- Hay crop silage only from 8 states:
  - MI, MN, NY, PA, VT, WA, WV, WI
- Small grain silages not estimated
- High moisture grain not estimated
Importance of Silage in Our 4-State Area

% US Production

Corn

Hay Crop
Ensiling Trends on US Dairy Farms (Hoard’s, 2002)
Implications of Ensiling Trends

- Crops are being ensiled wetter
  - Greater chance for clostridial (butyric acid) fermentation
  - Silage effluent
- Movement to silo types needing more management skills
Focus of Talk

Issues important to managing newer silo types

- Clostridial (butyric acid) silage
- Bunker density
- Bag density, losses
- New inoculants - *Lactobacillus buchneri*
Clostridial Silage

- Any silage with butyric acid > 0.5% DM
- Caused by clostridia that convert sugars or lactic acid to butyric acid
- Other clostridia convert amino acids to ammonia, amines
Problems With Clostridial Silage

In the silo:
- Increased DM loss
- Loss of energy

In the cow:
- Reduced intake
- Ketosis
Causes of Clostridial Silage

- Sufficient clostridia on the crop at ensiling

- Insufficient fermentation that does not stop their growth
Sources of Clostridia

- Soil and manure
- Avoid soil contamination
- Manure
  - Applied to alfalfa soon after cutting does not raise the number of clostridia on crop at harvest
  - Once regrowth has begun: potential problem
How Much Fermentation is Needed to Stop Clostridia?

![Graph showing critical pH levels for different moisture contents for alfalfa and corn.](image-url)
Moisture Content to Avoid Problems

- Corn
  - Not an issue except in spoiled areas

- Alfalfa
  - Bunkers, bags: < 65% moisture (70% in good conditions with rapid fill)
  - Wrapped bales: < 60% moisture
“I have a clostridial silage. What should I do?”

- If possible, you want to use rapidly.
  - Silage will get more clostridial with time

- However, not to transition and early lactation cows
  - Risk of ketosis

- Replacement heifers, far-off dry cows, late lactation cows
  - 50 g butyric acid/day per animal (Oetzel, UW)
  - Utilize fermentation analysis to formulate ration
Focus of Talk

Issues important to managing newer silo types

- Clostridial (butyric acid) silage
- **Bunker density**
- Bag density, losses
- New inoculants - *Lactobacillus buchneri*
Density

Important to:

- Reduce storage cost
- Increase dry matter recovery
- Reduce heating problems
Important Factors for Bunker Density - 168 Silo Survey

- Tractor Weight
- Packing Time
- Layer Thickness
- Height of Silage
- Moisture Content
### Bunker Density Calculator

**Spreadsheet to Calculate Average Silage Density in a Bunker Silo (English Units)**

- **Bunker Silo Wall Height (feet) (zero for silage pile)** = 10
- **Bunker Silo Maximum Silage Height (feet)** = 12
- **Silage Delivery Rate to Bunker (T AF/Hr)** = 25
  - Typical values 15-200 T AF/ hr
- **Silage Dry Matter Content (decimal ie 0.35)** = 0.35
  - Recommended range of DM content = 0.3-0.4
- **Silage Packing Layer Thickness (inches)** = 6
  - Recommended value is 6 inches or less
- **Packing Tractor - Each Tractor**
  - **Tractor Weight (lbs)** =
    - Tractor #1: 30000
    - Tractor #2: 0
    - Tractor #3: 0
    - Tractor #4: 0
- **Proportioned Total Tractor Weight (lbs)** = 30000
- **Average Silage Height (feet)** = 11.0

**Packing Factor** = 591.6

**Est. Average Dry Matter Density (lbs DM/cu ft)** = 17.1

**Maximum Achievable DM Density (lbs DM/cu ft)** = 25.7

Values in green cells are intermediate calculations.

Values in pink cells are results of calculations.

Density greater than 14 lbs DM/cu ft is recommended.
Density greater than 28 lbs DM/cu ft is unrealistic.
## Bunker Density Calculator

<table>
<thead>
<tr>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>F</th>
<th>G</th>
<th>H</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bunker Silo Wall Height (feet) (zero for silage pile)</td>
<td>10</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>13-Jan-02</td>
</tr>
<tr>
<td>Bunker Silo Maximum Silage Height (feet)</td>
<td>12</td>
<td>Values in yellow cells are user changeable</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Silage Delivery Rate to Bunker (T AF/HR)</td>
<td>100</td>
<td>Typical values 15-200 T AF/hr</td>
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<td></td>
</tr>
<tr>
<td>Silage Dry Matter Content (decimal i.e. 0.35)</td>
<td>0.35</td>
<td>Recommended range of DM content = 0.3-0.4</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Silage Packing Layer Thickness (inches)</td>
<td>6</td>
<td>Recommended value is 6 inches or less</td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Packing Tractor - Each Tractor

<table>
<thead>
<tr>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tractor # 1</td>
<td>Typical tractor weight is 10,000-60,000 lbs</td>
<td>30000</td>
<td>100</td>
</tr>
<tr>
<td>Tractor # 2</td>
<td>Typical tractor weight is 10,000-60,000 lbs</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Tractor # 3</td>
<td>Typical tractor weight is 10,000-60,000 lbs</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Tractor # 4</td>
<td>Typical tractor weight is 10,000-60,000 lbs</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

### Proportioned Total Tractor Weight (lbs) = 30000

### Average Silage Height (feet) = 11.0

### Packing Factor = 295.8

### Est. Average Dry Matter Density (lbs DM/cu ft) = 12.7

### Maximum Achievable DM Density (lbs DM/cu ft) = 25.7
# Bunker Density Calculator

<table>
<thead>
<tr>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Bunker Silo Wall Height (feet) (zero for silage pile)</td>
<td>10</td>
<td></td>
<td></td>
<td>13-Jan-02</td>
</tr>
<tr>
<td>2</td>
<td>Bunker Silo Maximum Silage Height (feet)</td>
<td>12</td>
<td>Values in yellow cells are user changeable</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Silage Delivery Rate to Bunker (T AF/Hr)</td>
<td>100</td>
<td>Typical values 15-200 T AF/hr</td>
<td></td>
<td></td>
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<tr>
<td>4</td>
<td>Silage Dry Matter Content (decimal i.e. 0.35)</td>
<td>0.35</td>
<td>Recommended range of DM content = 0.3-0.4</td>
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<td></td>
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<tr>
<td>5</td>
<td>Silage Packing Layer Thickness (inches)</td>
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<td>Recommended value is 6 inches or less</td>
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<tr>
<td>6</td>
<td>Tractor #1 - Each Tractor</td>
<td>Tractor Weight (lbs)</td>
<td>Tractor Packing Time (% of Filling Time)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Typical tractor weight is 10,000-60,000 lbs</td>
<td>30,000</td>
<td>100</td>
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<td>8</td>
<td>Typical tractor weight is 10,000-60,000 lbs</td>
<td>100,000</td>
<td>100</td>
<td></td>
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<tr>
<td>9</td>
<td>Typical tractor weight is 10,000-60,000 lbs</td>
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<tr>
<td>10</td>
<td>Typical tractor weight is 10,000-60,000 lbs</td>
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<td>0</td>
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<tr>
<td>11</td>
<td>Proportioned Total Tractor Weight (lbs)</td>
<td>40,000</td>
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<tr>
<td>12</td>
<td>Average Silage Height (feet)</td>
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<td>Values in green cells are intermediate calculations</td>
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<td></td>
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<tr>
<td>13</td>
<td>Packing Factor =</td>
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<td></td>
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<tr>
<td>14</td>
<td>Est. Average Dry Matter Density (lbs DM/cu ft)</td>
<td>12.7</td>
<td>Density greater than 14 lbs DM/cu ft is recommended</td>
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<td></td>
</tr>
<tr>
<td>15</td>
<td>Maximum Achievable DM Density (lbs DM/cu ft)</td>
<td>25.7</td>
<td>Density greater than 28 lbs DM/cu ft is unrealistic</td>
<td></td>
<td></td>
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</tbody>
</table>

C:\my documents\B.J.Holmes spreadsheets this computer\Silage Storage\bunkdensity_master1.xls
**Bunker Density Calculator**

<table>
<thead>
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<td>Proportioned Total Tractor Weight (lbs) =</td>
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Packing Factor = 416.3

Estimated Average Dry Matter Density (lbs DM/cu ft) = 14.5

Maximum Achievable DM Density (lbs DM/cu ft) = 25.7
# Bunker Density Calculator

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</tr>
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</tr>
<tr>
<td>Average Silage Height (feet)</td>
<td>11.0</td>
<td>Values in green cells are intermediate calculations</td>
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</table>

## Packing Factor = 627.5

<table>
<thead>
<tr>
<th>Est. Average Dry Matter Density (lbs DM/cu ft)</th>
<th>17.6</th>
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</thead>
</table>

<table>
<thead>
<tr>
<th>Maximum Achievable DM Density (lbs DM/cu ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>25.7</td>
</tr>
</tbody>
</table>

Values in pink cells are results of calculations.

Density greater than 14 lbs DM/cu ft is recommended.

Density greater than 28 lbs DM/cu ft is unrealistic.
Studies to Confirm Survey Results

- Pilot-scale trials as pictured at right
  - Alfalfa
  - Corn
- Eventually farm-scale experiments
Preliminary Pilot-Scale Results

- Tractor weight makes a large difference on density
- Differences increase with each additional layer
- Layer thickness not as important as in survey
Preliminary Pilot-Scale Results

- Time is important
- But each added pass produces a smaller increase in density
- How time is achieved does not appear important

![Graph showing compaction time and relative density]
Preliminary Pilot-Scale Results

- So results are not completely similar to survey results

- Which are correct?
  - Don’t know! Reason to do the field-scale trials.

- When we do know, we will update the Bunker Density Calculator
Focus of Talk

Issues important to managing newer silo types

- Clostridial (butyric acid) silage
- Bunker density
- Bag density, losses
- New inoculants - *Lactobacillus buchneri*
Bag Silos

- Little except for sales literature on density and losses from bag silos
- Yet both are critical in decision making
  - Comparing silo types when adding capacity
  - Managing feed inventory once you have them
Objectives

- Monitor filling, emptying of bag silos to:
  - Measure densities and losses
  - Determine factors affecting each
9 ft. Kelly-Ryan
8 ft. Ag Bag
Dry Matter Densities in Hay Crop Silages

Average slope = 0.19 lbs DM/ft³-% DM
Dry Matter Densities in Corn Silages

Average slope=??
<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>13.4</td>
<td>13.4</td>
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<tr>
<td></td>
<td></td>
<td>No</td>
<td>13.1</td>
<td>15.4</td>
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<tr>
<td>9’ Ag Bag</td>
<td>Arl</td>
<td>Yes</td>
<td>13.5</td>
<td>11.0</td>
</tr>
<tr>
<td>9’ K R</td>
<td></td>
<td>Yes</td>
<td>14.2</td>
<td>12.2</td>
</tr>
<tr>
<td>9’ K R</td>
<td></td>
<td>No</td>
<td>11.6</td>
<td>11.1</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%
## Range of Losses (% DM) 24 Bags

<table>
<thead>
<tr>
<th>Type</th>
<th>Range</th>
<th>Average</th>
<th>Worst 6*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gas/Uncollected</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
Spoilage Losses vs. DM Content

Dry Matter Content, %

DM Loss, %

Hay
Corn
Spoilage Losses vs. Emptying Mid-Point Date

![Graph showing DM Loss, % over time with Hay and Corn data points]
Gaseous/Uncollected Losses vs. DM Content

DM Loss, %

Dry Matter Content, %

-2 23

Hay
Corn
High Spoilage

Burst Bag
Gaseous/Uncollected Losses vs. Feed Out Rate

DM Loss, %

Feed Out Rate, in/d

Hay
Corn
High Spoilage
Gaseous/Uncollected Losses vs. Emptying Mid-Point Date

DM Loss, %

-2  3  8  13  18  23

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

Hay
Corn
High Spoilage
Focus of Talk

Issues important to managing newer silo types

- Clostridial (butyric acid) silage
- Bunker density
- Bag density, losses
- New inoculants - *Lactobacillus buchneri*
Standard Silage Inoculants

- Homofermentative lactic acid bacteria
- Shift fermentation to lactic acid, away from acetic acid & ethanol
- Guarantee a fast fermentation
- Improve DM recovery: 2-3%
- Improve animal performance: 3-5%
However, One Problem!

- Inoculants can reduce aerobic stability or bunk life
- Reductions are largely in corn and small grain silages

Aerobic Stability in All Silages as Affected by Inoculants

(Muck and Kung, 1997)
What Changes Are Occurring in Inoculants?

- Inoculant industry is looking for solutions to the aerobic stability problem

- Potential solutions:
  - Better standard inoculants with the ability to kill spoilage microorganisms
  - Heterofermentative LAB: *Lactobacillus buchneri*
  - LAB plus chemical inhibitor
L. buchneri Silage Inoculants - Expectations

- Can convert lactic to acetic
- Improve aerobic stability
- Higher pH
- Improve DM recovery but less than with a homofermenter
- Improve animal performance compared to a heating untreated silage; high acetic could be negative
## Pilot-Scale Results

### pH and Fermentation

<table>
<thead>
<tr>
<th>Treatment</th>
<th>pH</th>
<th>Lactic</th>
<th>Acetic</th>
<th>Ethanol</th>
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<tbody>
<tr>
<td>Untreated</td>
<td>3.64</td>
<td>7.3</td>
<td>1.8</td>
<td>0.9</td>
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<tr>
<td>Standard A</td>
<td>3.71</td>
<td>8.9</td>
<td>2.3</td>
<td>2.0</td>
</tr>
<tr>
<td>Standard B</td>
<td>3.65</td>
<td>8.1</td>
<td>2.0</td>
<td>1.3</td>
</tr>
<tr>
<td>Standard C</td>
<td>3.62</td>
<td>7.5</td>
<td>1.6</td>
<td>1.0</td>
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<tr>
<td>Enhanced A</td>
<td>3.64</td>
<td>8.2</td>
<td>1.8</td>
<td>0.9</td>
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<td>L. buchneri A</td>
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<td>7.0</td>
<td>1.1</td>
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<td>L. buchneri B</td>
<td>3.84</td>
<td>6.5</td>
<td>5.5</td>
<td>1.2</td>
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</table>

(Muck, 2002)
## Pilot-Scale Results

**Relative aerobic stability, hours**

<table>
<thead>
<tr>
<th>Treatment</th>
<th>1999</th>
<th>2000</th>
<th>2001</th>
</tr>
</thead>
<tbody>
<tr>
<td>Untreated</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Standard A</td>
<td>16</td>
<td>-13</td>
<td>-39</td>
</tr>
<tr>
<td>Standard B</td>
<td>-4</td>
<td>-20</td>
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</tr>
<tr>
<td>Standard C</td>
<td>-25</td>
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<td>-9</td>
</tr>
<tr>
<td>Enhanced A</td>
<td>-24</td>
<td>-27</td>
<td>29</td>
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<tr>
<td>L. buchneri A</td>
<td>142</td>
<td>100</td>
<td>811</td>
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<tr>
<td>L. buchneri B</td>
<td>103</td>
<td>22</td>
<td>454</td>
</tr>
</tbody>
</table>

(Muck, 2002)
## Pilot-Scale Results

### Dry matter losses, %

<table>
<thead>
<tr>
<th>Treatment</th>
<th>1999</th>
<th>2000</th>
<th>2001</th>
</tr>
</thead>
<tbody>
<tr>
<td>Untreated</td>
<td>33</td>
<td>16</td>
<td>14</td>
</tr>
<tr>
<td>Standard A</td>
<td>29</td>
<td>20</td>
<td>14</td>
</tr>
<tr>
<td>Standard B</td>
<td>27</td>
<td>18</td>
<td>12</td>
</tr>
<tr>
<td>Standard C</td>
<td>26</td>
<td>17</td>
<td>14</td>
</tr>
<tr>
<td>Enhanced A</td>
<td>25</td>
<td>21</td>
<td>17</td>
</tr>
<tr>
<td>L. buchneri A</td>
<td>30</td>
<td>18</td>
<td>17</td>
</tr>
<tr>
<td>L. buchneri B</td>
<td>32</td>
<td>17</td>
<td>21</td>
</tr>
</tbody>
</table>

(Muck, 2002)
Field-Scale Results

Dutch Corn Silage Trial

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Untreated</th>
<th>L. buchneri</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH</td>
<td>3.88</td>
<td>3.92</td>
</tr>
<tr>
<td>Lactic Acid, % DM</td>
<td>4.8</td>
<td>4.7</td>
</tr>
<tr>
<td>Acetic Acid, % DM</td>
<td>1.2</td>
<td>1.9</td>
</tr>
<tr>
<td>Yeasts, log(cfu/g)</td>
<td>7.1</td>
<td>5.7</td>
</tr>
<tr>
<td>Aerobic stability, hour</td>
<td>9</td>
<td>41</td>
</tr>
</tbody>
</table>
### Field-Scale Results

#### Dutch Corn Silage Trial Performance

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Untreated</th>
<th>L. buchneri</th>
</tr>
</thead>
<tbody>
<tr>
<td>DM Intake, lbs/day</td>
<td>45.9</td>
<td>45.0</td>
</tr>
<tr>
<td>Milk, lbs/day</td>
<td>85.5</td>
<td>85.5</td>
</tr>
<tr>
<td>Fat, lbs/day</td>
<td>3.61</td>
<td>3.61</td>
</tr>
<tr>
<td>Protein, lbs/day</td>
<td>2.77</td>
<td>2.83</td>
</tr>
</tbody>
</table>
Other L. buchneri Lactation Trials

- Aerobic stability: consistently increased
- Acetic acid:
  - Consistently increased; 0.4, 5.7 and 5.9% DM in high moisture corn, alfalfa and barley silages
- Dry matter intake: no effect
- Milk production: no effect
  - Avg. production: 69, 89 and 57 lbs./day for 3 studies
Overall Results with *L. buchneri* Silage Inoculants

- Slightly higher pH; increased acetic acid
- Aerobic stability: consistent increases
- Slower growers: 45-60 days storage time before having much effect on aerobic stability
- Dry matter recovery: most likely intermediate between untreated and standard inoculants
- Animal performance: no effects yet in trials
Goals In Using Inoculants?

Choice of inoculants depends on goals:

- Make a good silage perform better
- Aerobic stability improvement
Make a Good Silage Better

Standard inoculants are the best route to improve DM recovery, animal performance

- Good fit for hay crop silages
- Less likely to be successful on corn
  - Harder to get consistent improvements
  - Bunk life issues when they work
Aerobic Stability Problems

- Is the problem a management problem that can be solved without an additive?

- If not, *L. buchneri* looks like a good alternative to propionic acid or anhydrous ammonia
  - Safer to handle
  - Competitive cost
  - Similar effects on DM recovery, animal performance with all three additives
Final Issues with Using Any Inoculant

- These products work only if the bacteria go on the crop alive!
  - Store them properly: generally cool and dry
  - Don’t use chlorinated water to dilute unless the chlorine level is less than 1 ppm

- These bacteria cannot move around; they depend on you to spread them uniformly
Questions?