Harvest and Storage of Silage

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Silage Producers Short Course -- Lebanon, MO 11/10/2015

Silage Production

• Goal is to harvest and store forages in a manner that will allow for
  1. Maintaining integrity of feedstuffs
     • Minimize spoilage and DM loss
  2. Maximizing nutritional quality of forage crop

Discussion Points

• Process of fermentation
• Harvesting
• Moisture testing
• Storage
• Silage Inoculants
• Troubleshooting problems

Process of silage fermentation

• Phase 1 – Aerobic phase - lasts a few hours.
  – Continues until either O₂ supply or soluble carbohydrate is depleted.
  – Temperature increases due to respiration.
• Phase 2 – Begins when trapped O₂ supply is depleted.
  – Lasts 24 to 72 hrs.
  – Anaerobic fermentation begins.
  – Heterofermentative bacteria produce both acetic and lactic acids.
  – These bacteria survive between 7 and 5 pH.

Process of silage fermentation

• Phase 3 – Transitional phase that usually lasts only 24 hours.
  – Homofermentative bacteria rapidly drop pH through efficient production of lactic acid.
  – Temperature decreases and pH continues to drop.

Process of silage fermentation

• Phase 4 – Continuation of Phase 3 with stabilization of temperature.
  – Homofermentative bacteria convert water soluble carbohydrates to lactic acid.
  – In well fermented silage lactic acid can account for over 65% of total VFAs.
  – Corn silage can reach a final pH of 4.0.
  – Legumes and grasses have less water soluble carbohydrate and higher buffering capacity and usually reach a pH of 4.5.
  – Phases 2, 3, and 4 are usually completed in 10 days to 3 weeks from harvest.
Process of silage fermentation

- **Phase 5** – This phase lasts through the remainder of storage where the fermentation process is stable as long as oxygen does not penetrate silage.
  - Final temperature will be between 75 and 85 degrees F.

- **Phase 6** – This phase occurs during feed out.
  - Can result in substantial dry matter losses as oxygen is reintroduced into the fermented crop.
  - Proper management of the silage face and at the feed bunk can minimize dry matter losses and optimize feed intakes by dairy cows.

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**Harvest**

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**Changes in Corn Forage Yield and Quality with Harvest Date**

Source: Darby and Lauer (2002)
Changes in Corn Forage Yield and Quality with Harvest Date

Source: Darby and Lauer (2002)

Optimum harvest stage and moisture levels for major silage crops

<table>
<thead>
<tr>
<th>CROP</th>
<th>Harvest Stage</th>
<th>Dry Matter Content</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corn</td>
<td>1/2 to 2/3 milkline</td>
<td>≥32-33%</td>
</tr>
<tr>
<td>Alfalfa</td>
<td></td>
<td>65-75%</td>
</tr>
<tr>
<td>HMC/Cereals</td>
<td>boot to dough</td>
<td>35-45%</td>
</tr>
<tr>
<td>Cereals</td>
<td>boot</td>
<td>35-45%</td>
</tr>
<tr>
<td>Grasses</td>
<td>boot</td>
<td>35-45%</td>
</tr>
<tr>
<td>Alfalfa</td>
<td>bud to 1/10 bloom</td>
<td>35-45%</td>
</tr>
<tr>
<td>Bunker or bag Harvestore</td>
<td>bud to 1/10 bloom</td>
<td>40-55%</td>
</tr>
<tr>
<td>Harvestore</td>
<td>bud to 1/10 bloom</td>
<td>50-60%</td>
</tr>
</tbody>
</table>

Corn Silage Harvest Guidelines

- For good fermentation and minimum seepage:
  - Horizontal silo — 30 to 35% DM
  - Conventional upright — 32 to 37% DM
  - Oxygen-limiting upright — 40 to 45% DM
  - Bags — 30 to 40% DM

Expected Dry Matter Losses of Corn Silage Harvested at Different Moisture Contents

<table>
<thead>
<tr>
<th>Moisture</th>
<th>Harvest</th>
<th>Storage Percentage</th>
<th>Feeding</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>≥70</td>
<td>4.0</td>
<td>13.4</td>
<td>4.0</td>
<td>21.4</td>
</tr>
<tr>
<td>61-69</td>
<td>5.0</td>
<td>6.3</td>
<td>4.0</td>
<td>15.3</td>
</tr>
<tr>
<td>&lt;61</td>
<td>16.2</td>
<td>6.3</td>
<td>4.0</td>
<td>26.5</td>
</tr>
</tbody>
</table>
Effect of maturity on maximum milk yield

Maximun
milk yield (%)
99
97
95
93
91
90
80
70
60
50
40
30
20
10
0

Maturity
(milkline progress)
0.125
0.25
0.5
0.66
1
1+

Source: Johnson et al., 1999

Corn Kernel Milk Line Progression

Photo credits: Dupont Pioneer

Corn Silage Harvest Guidelines

- Generally 1/2 to 2/3 milk line will be 60% to 70% DM

Kernel Milk Stage "Triggers" for Timing Silage Harvest

<table>
<thead>
<tr>
<th>Silo structure</th>
<th>Ideal moisture content</th>
<th>Kernel milk stage &quot;trigger&quot;</th>
</tr>
</thead>
<tbody>
<tr>
<td>Horizontal bunker</td>
<td>70 to 65</td>
<td>80</td>
</tr>
<tr>
<td>Bag</td>
<td>70 to 60</td>
<td>80</td>
</tr>
<tr>
<td>Upright concrete stave</td>
<td>65 to 60</td>
<td>80</td>
</tr>
<tr>
<td>Upright oxygen limiting</td>
<td>60 to 50</td>
<td>80</td>
</tr>
</tbody>
</table>

"Trigger": kernel milk stage to begin checking silage moisture
Silage moisture decreases at an average rate of 0.5% per day during September
In-season Guidelines for Predicting Corn Silage Harvest Date

- Note hybrid maturity and planting date of fields intended for silage.
- Note tasseling (silking) date.
  - Kernels will be at 50% kernel milk (R5.5) about 42 to 47 days after silking.
- After milkline moves, use kernel milk triggers to time corn silage harvest.
  - Use a drydown rate of 0.5% per day to predict date when field will be ready for the storage structure.
  - See [http://cf.uisex.edu/ces/ag/silage/drydown/](http://cf.uisex.edu/ces/ag/silage/drydown/)
- Do final check prior to chopping.

Procedure for measuring plant moisture

1. Sample 3 to 5 plants in a row that is well bordered and representative.
2. Put in a plastic bag.
4. Chop as quickly as possible.
5. Measure moisture using NIR spectroscopy and/or by drying using a Koster oven, microwave, or convection oven.

Options for drying forages

Koster Tester

A Vortex Forage and Biomass Sample Dryer
[http://extension.psu.edu/publications/i-101](http://extension.psu.edu/publications/i-101)

G3151, Using a Microwave Oven to Determine Moisture in Forages
[http://extension.missouri.edu/p/G3151](http://extension.missouri.edu/p/G3151)

Effect of maturity on maximum milk yield

Source: Johnson et al., 1999

Drying Hay Crops for Silage

- Plant respiration rate is highest at cutting and gradually declines until plant moisture content drops below 60%.
- Rapid initial drying to lose the first 15% moisture will reduce losses of starch and sugars and preserve more total digestible nutrients in the harvested forage.

Drying hay crops for silage

Figure 2. Effect of moisture on silage quality: Arlington, WI; July 13, 1997.
Processing corn silage

- A lot of work has been done to evaluate the benefits of processing
- Not all trials agree on the magnitude of improvement but the trend is toward higher digestibility and animal performance from processed silage

### Processing Corn Silage

![Figure 1. Relationship between maturity and energy content in silage corn with and without processing.](image)

### Processing Affects Rumen Digestion

![Figure 4. Effect of percent whole kernel, starch, and intact kernel on intake and voluntary intake of corn.](image)

### Affects on Total Tract Digestion

![Figure 2. Total tract digestibility of dry matter (DM), starch, NDF, and fat.](image)

### Processing Effect on Intact Kernels, Starch Digestibility

![Figure 3. Effect of percent whole kernel, starch, and intact kernel on intake and voluntary intake of corn.](image)
Effects of Processing at Progressing Stages of Maturity - TMR

Effect of Processing on Milk Production and Composition

Cutting Height

- Nutritional quality of silage can be improved with higher cutting
- Obviously yield will also be affected

Harvesting Corn Silage

- Sharpen knives
  - Uniform chop
  - Reduces energy requirement for harvest
- Chop at correct length
  - Recommended theoretical length of chop (TLC)
    - Grass and alfalfa – 3/8 to 1/2 inch
    - Unprocessed corn silage – 3/8 to 1/2 inch
    - Processed corn silage – 3/4 inch
    - Brown midrib silage requires longer TLC

Monitoring chop length

- Forage Particle Separator
  - Basic model has 3 screens
  - To measure chop length of silage use the top 2
    - 3/4 inch and 5/16 inch
  - Ideally, after sieving the material should be distributed:
    - 25-50% < 5/16 inch (bottom screen)
    - 40-50% between 5/16 and 3/4 inch (middle screen)
    - 10-20% > than 3/4 inch top (tray)
**Storage**

- A high density is desired to minimize spoilage losses and increase silo capacity.
- The most important factors to achieve high density include:
  - Harvesting at correct DM content
  - Spreading silage thinly
  - Using a heavy tractor(s) to pack
  - Packing time
  - Silo height

**Filling the Silo**

- Fill quickly – preferably in no more than three days
- Pack in layers no more than 6 inches deep
- Pack well – 15# DM/cubic ft.
- Storage Density Calculator
  - [http://www.uwex.edu/ces/crops/uwforage/DocumentationStorageDensity.pdf](http://www.uwex.edu/ces/crops/uwforage/DocumentationStorageDensity.pdf)

**Filling Rate (T/Hr)**

\[
\text{Filling Rate (T/Hr)} = \frac{\text{Packing Vehicle(s) Weight}}{800}
\]

**Packing Vehicle(s) Weight = Filling Rate (T/Hr) X 800**

**Example:**
- If your tractor weighs 26,000# you can fill at: \( \frac{26,000}{800} = 32 \text{T/Hr} \)
- If your chopper can deliver 45T/Hr you will need: \( 45 \times 800 = 36,000\# \text{ Packing Wt.} \)

**TABLE 1. Dry matter loss as influenced by silage density**

<table>
<thead>
<tr>
<th>Dry Matter 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>

**Progressive wedge**
- Minimizes surface exposure to air and
- Maximizes packing efficiency
Covering

- Sealing the silo is crucial to minimize storage losses and make a stable silage
- Kansas study found average losses in top 18” to be > 40% in uncovered bunkers

Proper Plastic Sheeting
Charles Staples, U of Fla.

- 4 mil – Good(?), 6 mil – Better, 8 mil – Best
- UV Protection
- Two layers better than 1
- Oxygen barrier plastic “Silostop”
  - 5 mil thickness
  - Claims superior O₂ exclusion
  - Oxygen transfer rate:
    - Conventional 5 mil plastic – OTR = 1800 cc O₂/m²/day
    - Oxygen barrier – OTR = 29
    - Can reduce DM loss in outer 1.5 to 3 feet by 50%

Sealing Recommendations from Charles Staples, U of Fla.

- Sealing the edges of a bunker can be challenging – this is an area vulnerable to deterioration.
- Plastic on sidewalls can help.
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Silage Inoculants

- Two types
  - **Homofermentative**
    - Produce lactic acid
    - Lactobacillus, Pediococcus, Enterococcus
    - *Used to stimulate rapid fermentation*
  - **Heterofermentative**
    - Produce lactic acid, acetic acid or ethanol, and carbon dioxide
    - Lactobacillus *buchneri*
    - *Used to inhibit aerobic spoilage*
Homofermentative Inoculants
(Fermentation aids)

- Improve the initial fermentation process
  - Speeds up lactic acid production
  - Prevents growth of undesirable microbes (Enterobacteria, Clostridia)
- Can lead to improvements in dry matter recovery (2%-3%)
- Sometimes lead to improvements in animal performance

Heterofermentative Inoculants
(Spoilage Inhibitors)

- Have little effect on initial silage fermentation
- Improves aerobic stability of silage
- Increases production of acetic acid which is a potent inhibitor of yeasts and molds

Heterofermentative Inoculants

- Use to extend shelf life (bunk life)
  - Large bunkers or piles where the face may be too wide
  - Silage that will be sold and left on intermediate feeding piles for several days
  - Bags or bunkers that will be fed out during summer
Choosing an Inoculant

- An effective silage inoculant will have independent, statistically analyzed, and published data supporting its use – the more the better.

Feedout

Managing aerobic stability

- Silage quality can deteriorate rapidly during feedout.
- The exposed silage surface is open to air (oxygen) for long periods of time.
- In the presence of oxygen, yeast cells and mold spores that were dormant in the anaerobic environment can become active.
- Yeast growth is the primary cause of silage heating and is the primary cause of DM and energy losses at feedout.

Silo face management

Photo credits: Kung, U of Delaware

Key steps to reducing DM loss and maintaining silage quality at feedout

- Use proper harvesting and storage techniques
- Feed at least 6 inches of silage per day from a bunker silo face
- Use good face management
- DO NOT feed moldy silage; it can cause serious health problems and/or production losses!

Effect of Feeding Spoiled Silage on DMI and Total DM Digestibility

Source: Whitlock et al., 2008
Fermentation Analysis

- Can tell us the quality of fermentation that has occurred
- Can help explain poor nutritive value or low intake
- Should be used in conjunction with standard chemical analysis

Troubleshooting silage problems

- pH too high
  - Cause could be slow fermentation, yeast growth
  - No smell, alcoholic, or earthy
  - Could be due to slow filling, poor packing, chop length
  - Inoculant may help prevent

Troubleshooting silage problems

- Silage heats
  - Can be caused by yeast, bacillus growth
  - Could be caused by slow filling, poor packing, chop length
  - Spoilage inhibitor may help prevent

Troubleshooting silage problems

- Mold
  - Musty smell
  - Grows in presence of air
  - Possible causes
    - Poor packing
    - Poor sealing
    - Slow feedout

Troubleshooting silage problems

- Silage pH too low
  - Sweet acid smell
  - Usually results from activity of “wild” lactobacilli
  - Often follows a slow initial fermentation
    - Fast fermentation usually prevents establishment of “wild” lactobacilli
  - To avoid practice fast fill rate, good packing, and use a homolactic inoculant
Troubleshooting silage problems

• High ammonia
  — Caused by Enterococcus or Sreptococcus faecium - bacteria that break down protein
  — Or possibly caused by clostridia

• Clostridial fermentation
  — Can occur with wet silage or with high ash content - soil inclusion
  — Silage will have a fecal/putrid/decaying odor
  — Intake will be low

Recommended references

• Team Forage – University of Wisconsin Extension – http://fyi.uwex.edu/forage/
• QualitySilage.com - http://qualitysilage.com/
• The Silage Zone – Pioneer
  https://www.pioneer.com/home/site/us/livestock-feed-nutrition/

Take Home Messages

• Manage to maximize
  — DM recovery
  — Forage quality
• Harvest at correct time
  — Moisture content
  — Maturity
• Chop and process correctly
• Use inoculants appropriately

Take Home Messages

• Fill quickly
• Pack densely
• Cover well
• Feedout to minimize aerobic instability

The End of the Row – Questions?
Thanks for your attention!