Baled Silage

Wayne Coblentz
USDA-ARS
US Dairy Forage Research Center
Marshfield, WI
Goal: Silage Preservation

• Anaerobic (without air) bacteria convert plant sugars to lactic acid.

• This process lowers the pH and preserves the forage as silage.
Sequence of Phases in the Silo for Good Fermentation

Source: R. E. Pitt
Lactic Acid
Bacteria
Consuming
Sugar

Lactic Acid
The “Good Silage” Acid
Regardless of silo type, most management principles are the same.

- start with high-quality forage
• manage the moisture content of the forage

• excessively wet or dry silages can both be problematic

• standards vary somewhat with silo type
• eliminate air
- maintain silo integrity

- particularly important for plastic structures
• avoid poor feedout management

• too much exposure to air is problematic
Baled Silage: Some Specifics

1. Baled Silage vs. Hay
2. Baled vs. Conventional Silage
3. Crop Factors
4. Moisture Management
5. Elimination of Air
6. Feedout Management
1. Why Choose Baled Silage over Hay?

- well-made baled silage will often exhibit better quality characteristics than corresponding hays
  - increased leaf losses (hay)
  - harvest delays (inclement weather)
  - rain damage
  - spontaneous heating
  - weathering after baling (outdoor storage)
Delaying Harvest: NDF (%) within KY-31 Tall Fescue at Various Maturities

Source: C.S. Hoveland and N.S. Hill, University of Georgia
Delaying Haying for Favorable Weather

Annual Ryegrass

McCormick et al. (1998): annual ryegrass (1993-94); silages harvested mid-April, hay in early May
Risks of Rain Damage in Hay Production
(Scarborough et al., 2005)

Dry Matter Loss - Orchardgrass vs. Bermudagrass

Dry Matter Loss (%)

Rainfall (inches)

OG - 15.3%
BER - 13.0%
Hancock and Collins (2006): *alfalfa harvested at mid-bud stage of maturity; hay baled at 19.8% moisture and stored outside, uncovered; hay received two rainfall events totaling 0.6 inches prior to baling.*
In Vitro True Digestibility

N = 32 baling treatments

Initial = 77.2%, which corresponds generally to ΔIVTD = 0 on the y-axis

Wisconsin Round Bale Study
Heat-Damaged Hay
(2006-07)
Combined Effects of Rain Damage and Modest Spontaneous Heating

Hancock and Collins (2006): alfalfa harvested at mid-bud stage of maturity; hay baled at 19.8% moisture and stored outside, uncovered; hay received two rainfall events totaling 0.6 inches prior to baling.
2. Baled Silage vs. Precision-Chopped Haylage
How Do They Compare?

• lack of chopping action forces sugars to diffuse from inside the plant to reach lactic-acid bacteria located on the outside of the forage.

• although dependent on many factors, baled silage may be less dense (DM/ft³) than some other (chopped) silo types, which also may restrict availability of sugars to lactic acid bacteria.

• lower bale density, and greater ratio of surface area to forage DM, potentially make baled silage more susceptible to entrapment and/or penetration by O₂.

• recommendations for the moisture content of baled silage are 5 to 20 percentage units lower than for chopped forages; this alone will restrict fermentation.
Baled vs. Precision-Chopped Silage
Alfalfa/Grass

Muck (2006) – adapted from Nicholson et al. 1991; average moisture content of silages was 61%
Fermentation Characteristics
Chopped Haylage vs. Baled Silage

McCormick et al. (1998)

- annual ryegrass (1993-94)
- 4 x 4 bales
- silages harvested mid-April in southeast Louisiana
3. Effects of Crop Factors on Baled Silage

- harvest high-quality forages – expensive equipment generally will not improve forage quality
- damaged, or mismanaged forages that ferment poorly in conventional silo types also are likely to make poor baled silage
- harvest at proper growth stage (sugar status)
- remember that forage species are inherently different
  - legumes ≠ cool-season (cs) grasses
  - cs grasses ≠ warm-season (ws) grasses
  - ws annuals ≠ ws perennials
Crop Factors
Sugar Status: Nonstructural CHO in Stem Bases of Perennial Cool-Season Grasses

- Green up
- Stem elongation
- Anthesis
- Mature seed
## Concentrations of CHO in Orchardgrass

<table>
<thead>
<tr>
<th>Plant Part</th>
<th>Proportion of Plant Weight</th>
<th>Reducing Sugars</th>
<th>Sucrose</th>
<th>Fructan</th>
</tr>
</thead>
<tbody>
<tr>
<td>Leaf – top 2/3</td>
<td>14.0%</td>
<td>1.4%</td>
<td>8.4%</td>
<td>7.6%</td>
</tr>
<tr>
<td>Leaf – lower 1/3</td>
<td>12.1%</td>
<td>1.2%</td>
<td>5.8%</td>
<td>22.0%</td>
</tr>
<tr>
<td>Tiller base (upper)</td>
<td>9.4%</td>
<td>1.9%</td>
<td>3.6%</td>
<td>23.7%</td>
</tr>
<tr>
<td>Tiller base (lower)</td>
<td>23.6%</td>
<td>0.7%</td>
<td>2.6%</td>
<td>36.2%</td>
</tr>
<tr>
<td>Roots</td>
<td>40.9%</td>
<td>1.2%</td>
<td>8.9%</td>
<td>8.2%</td>
</tr>
</tbody>
</table>

Sprague and Sullivan (1950)
Species Differences: Fermentation Characteristics

Han et al. (2006): mean of ideal (48.8%) and low (29.5%) moisture bales
Species Differences: Effects on pH

Han et al. (2006): mean of ideal (48.8%) and low (29.5%) moisture bales
4. Moisture Management for Baled Silage

- Generally, baled silage should be packaged at 40 to 60% moisture; the average for the whole field or group of bales should be about 50%.

- Bale weight can be a safety/equipment issue.

- Systems for baled silage will generally accommodate excessively dry forages better than excessively wet ones.
  - clostridial fermentations (wet)
  - bale deformation, tensile stress on plastic (wet)
  - migration/concentration of water

- moisture in the plant ≠ moisture on the plant
**Typical Compositions of Grass Silages Produced by Five Different Types of Fermentation.**

<table>
<thead>
<tr>
<th>Item</th>
<th>LAC</th>
<th>BUT</th>
<th>ACE</th>
<th>WILT</th>
<th>STER</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dry matter, %</td>
<td>19.0</td>
<td>17.0</td>
<td>17.6</td>
<td>30.8</td>
<td>21.2</td>
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<tr>
<td>pH</td>
<td>3.9</td>
<td>5.2</td>
<td>4.8</td>
<td>4.2</td>
<td>5.1</td>
</tr>
<tr>
<td>Protein N, % of N</td>
<td>23.5</td>
<td>35.3</td>
<td>44.0</td>
<td>28.9</td>
<td>74.0</td>
</tr>
<tr>
<td>Ammonia N, % of N</td>
<td>7.8</td>
<td>24.6</td>
<td>12.8</td>
<td>8.3</td>
<td>3.0</td>
</tr>
<tr>
<td>Lactic acid, %</td>
<td>10.2</td>
<td>0.1</td>
<td>3.4</td>
<td>5.9</td>
<td>2.6</td>
</tr>
<tr>
<td>Acetic acid, %</td>
<td>3.6</td>
<td>2.4</td>
<td>9.7</td>
<td>2.4</td>
<td>1.0</td>
</tr>
<tr>
<td>Butyric acid, %</td>
<td>0.1</td>
<td>3.5</td>
<td>0.2</td>
<td>0.1</td>
<td>0.1</td>
</tr>
<tr>
<td>WSC, %</td>
<td>1.0</td>
<td>0.6</td>
<td>0.3</td>
<td>4.8</td>
<td>13.3</td>
</tr>
</tbody>
</table>

Source: McDonald and Edwards (1976)
Moisture Management
(Clostridial Fermentations)

Some Characteristics of High-Risk Forages

- high moisture content (after ensiling)
  - direct cut
  - immature, rapidly growing
- highly contaminated with dirt, especially if manured
  - low sugar
  - high buffering capacity
  - high protein
  - leguminous
  - non-homogenous forages (baled silage)
- anything that slows or limits pH decline in wet forages
Moisture Management
(Clostridial Fermentations)

Principle Fermentation Products/Characteristics

- ammonia
- amines
- butyric acid
- high pH
- low lactic acid
- high DM losses
- poor intake by cattle

Solutions/Prevention

- wilt at risk forages to <65% moisture (<60% for baled silage)
- avoid soil contamination, especially if soil is manured
- optimize fermentation/pH decline
Clostridial Fermentations

Clostridial spores

Sugar and Lactic Acid

Butyric Acid
“Bad, Evil-Smelling Silage”
Enterobacteriaceae bacteria

Results = acetate, CO$_2$, lactate, ethanol, and H$_2$
Direct (62.8%) and Wilted (47.4%) Late-Harvested Eastern Gamagrass Silage (July 1995; Manhattan, KS)
Effects of Moisture Content on Silage pH

Hancock and Collins (2006): combined data from two trials; alfalfa harvested at mid-bud stage of maturity
Effects of Moisture Content on Lactic Acid

Hancock and Collins (2006): combined data from two trials; alfalfa harvested at mid-bud stage of maturity
Effects of Moisture Content and Rain-Damage on Fermentation

Borreani and Tabacco (2006)
Effects of Moisture Content on Bale Deformation (ft vertical/ft horizontal)

Hancock and Collins (2006): combined data from two trials; alfalfa harvested at mid-bud stage of maturity; estimate for hay is mean of bales made at 16.6 and 19.8% moisture, and stored outdoors, uncovered.
5. Elimination of Air
• causes respiration of plant sugars to CO$_2$, water, and heat
• reduces pool of fermentable CHO (sugars)
• dry matter loss
• increases (indirectly) fiber content of the silage
• decreases energy density of silage
• heat damage to silage proteins
- reduce ground speed
- increase PTO speed
- thinner windrows will increase revolutions/bale
- manage moisture appropriately (≈ 50%)
- maintain constant bale size
- baler/operator experience

bulk density >10 lbs DM/ft³
### Effects of Bale Density on Fermentation

<table>
<thead>
<tr>
<th>Density, lbs/ft³</th>
<th>12.9</th>
<th>10.9</th>
<th>12.4</th>
<th>10.4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moisture</td>
<td>------ 58.7%</td>
<td>------ 52.4%</td>
<td>-------</td>
<td>------</td>
</tr>
<tr>
<td>pH</td>
<td>4.7</td>
<td>4.9</td>
<td>4.8</td>
<td>5.1</td>
</tr>
<tr>
<td>Lactic acid, %</td>
<td>7.0</td>
<td>6.5</td>
<td>7.1</td>
<td>6.3</td>
</tr>
<tr>
<td>Acetic acid, %</td>
<td>2.4</td>
<td>3.8</td>
<td>3.3</td>
<td>2.0</td>
</tr>
<tr>
<td>Max temp, °F</td>
<td>107</td>
<td>109</td>
<td>108</td>
<td>106</td>
</tr>
<tr>
<td>DM REC, %</td>
<td>98.6</td>
<td>98.6</td>
<td>97.8</td>
<td>98.3</td>
</tr>
</tbody>
</table>

Han et al. (2004): high density bales created at 842 x 10³ Pa of chamber pressure; lower density bales made at 421 x 10³ Pa.
Sealing the Bale

- lack of uniformity will create air pockets for in-line wrapped bales
- use UV-resistant plastic
- wrap as quickly as possible after baling (within 2 hours is ideal)
- use (at least) four layers of stretched plastic (six for long-term storage and/or in southern states)
- storage site selection/maintenance is important
- do not puncture plastic - isolate from cattle, pets, and vermin
- patch holes with appropriate tape
Hydraulic Bale Grapple
## Effects of Delaying Wrapping on Internal Bale Temperature (63% Moisture)

<table>
<thead>
<tr>
<th>Wrap</th>
<th>Delay (h)</th>
<th>At Wrapping</th>
<th>Day 1*</th>
<th>Day 2</th>
<th>Day 4</th>
<th>Day 6</th>
<th>Day 14</th>
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<tbody>
<tr>
<td></td>
<td></td>
<td>°F</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No wrap</td>
<td>0</td>
<td>91</td>
<td>93</td>
<td>95</td>
<td>89</td>
<td>84</td>
<td>76</td>
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<tr>
<td></td>
<td>24</td>
<td>110</td>
<td>119</td>
<td>114</td>
<td>101</td>
<td>92</td>
<td>75</td>
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<tr>
<td></td>
<td>48</td>
<td>136</td>
<td>142</td>
<td>130</td>
<td>109</td>
<td>95</td>
<td>72</td>
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<tr>
<td></td>
<td>96</td>
<td>147</td>
<td>145</td>
<td>133</td>
<td>110</td>
<td>92</td>
<td>73</td>
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</tbody>
</table>

Vough et al. (2006): data adapted from Undersander et al. (2003); all square bales of alfalfa wrapped with eight mils of plastic film.

* Denotes days from wrapping.
### Effects of Wrapping Layers on Fermentation and Alfalfa Forage Quality

Hancock and Collins (2006)

<table>
<thead>
<tr>
<th>Trial</th>
<th>Moisture</th>
<th>Plastic</th>
<th>NDF</th>
<th>ADF</th>
<th>Lactic Acid</th>
<th>pH</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>layers</td>
<td>%</td>
<td>%</td>
<td>%</td>
<td>%</td>
</tr>
<tr>
<td>1</td>
<td>50.2</td>
<td>2</td>
<td>42.6</td>
<td>32.2</td>
<td>1.33</td>
<td>4.80</td>
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<tr>
<td></td>
<td>4</td>
<td>38.9</td>
<td>30.1</td>
<td>1.96</td>
<td>4.88</td>
<td></td>
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<tr>
<td></td>
<td>6</td>
<td>39.8</td>
<td>30.4</td>
<td>1.68</td>
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<tr>
<td></td>
<td>37.4</td>
<td>2</td>
<td>43.3</td>
<td>31.5</td>
<td>2.56</td>
<td>5.81</td>
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<td>29.7</td>
<td>1.50</td>
<td>4.60</td>
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<td></td>
<td>6</td>
<td>39.6</td>
<td>30.2</td>
<td>1.51</td>
<td>4.98</td>
<td></td>
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<tr>
<td>2</td>
<td>61.3</td>
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<td>35.9</td>
<td>24.3</td>
<td>4.52</td>
<td>4.49</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>34.5</td>
<td>23.0</td>
<td>4.47</td>
<td>4.48</td>
<td></td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>33.3</td>
<td>24.0</td>
<td>4.64</td>
<td>4.62</td>
<td></td>
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</tbody>
</table>
6. Feedout Management
Aerobic Stability of Wheat and Orchardgrass Baled Silage

Wheat
- harvested at milk stage
- 37.6% moisture
- 11.1 lbs DM/ft³

Orchardgrass
- harvested at heading stage
- 45.6% moisture
- 13.6 lbs DM/ft³
Rhein et al. (2005)
University of Arkansas
Surface pH after Exposure

Rhein et al. (2005)
## Comparisons of Stable and Reactor Wheat Baled Silage

<table>
<thead>
<tr>
<th>Treatment</th>
<th>DM Recovery</th>
<th>Visual Score</th>
<th>Final pH</th>
<th>MAX Temp</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>%</td>
<td></td>
<td></td>
<td>°F</td>
</tr>
<tr>
<td>Surface</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stable</td>
<td>- - -</td>
<td>1.00</td>
<td>4.81</td>
<td>52.0</td>
</tr>
<tr>
<td>Reactor</td>
<td>- - -</td>
<td>4.00</td>
<td>7.91</td>
<td>139.4</td>
</tr>
<tr>
<td>Center</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stable</td>
<td>100.0</td>
<td>- - -</td>
<td>5.02</td>
<td>47.8</td>
</tr>
<tr>
<td>Reactor</td>
<td>92.8</td>
<td>- - -</td>
<td>5.49</td>
<td>85.3</td>
</tr>
</tbody>
</table>

Rhein et al. (2005)
Summary

• Producers can make good silage using proper baling and wrapping techniques.

• Most principles of management for conventional chopped silage still apply to baled silage.

• Moisture management is critical; baled silage techniques will accommodate drier (<50%) forages much better than relatively wet (>65%) ones.
Summary

• Fermentation may occur at a slower rate for baled silage because forages are ensiled on a whole-plant basis, and are usually drier at harvest.

• As a result, producers should diligently address other management details, such as maximizing bale density, applying plastic wrap promptly and properly, and protecting the wrapped product from damage until feeding.