Alkaline Treatment of Residue
Matt Luebbe and Adam Shreck

Introduction
- Energy costs
- Alternative resources
- Availability of residues
  - Corn
  - Wheat
  - Soybean stubble

Replacing corn
- WDGS
  - ~130% value of corn @ 40% diet DM (Bremer et al., 2010)
- Roughage
  - Decreased performance (Bartle et al., 1994)
  - Higher cost per unit energy
  - Feeding treated roughage with WDGS
- Limited research
  - NE, IA, IL

History
- Chemical treatment began in 1880’s
  - Started with paper making
  - Observation of increased cellulose digestibility
- Alkali
- Peroxides
- Ammonia

Beckman Method
- 1920’s
- NaOH
- Soak residue for 18 h to 3 days
- 2 tank system
- High water requirement
- Pollution
- DM losses 20-25%
- Modifications improved feasibility
  - Combining NaOH and CaOH

Hydrolitic
- 1. Sodium Hydroxide
- 2. Calcium Hydroxide
- 3. Potassium Hydroxide
- 4. Ammonium Hydroxide
- 5. Anhydrous Ammonia
- 6. Urea

Oxidative
- 1. Hydrogen Peroxide
- 2. Ozone
- 3. Sulfur Dioxide
- 4. Sodium Chlorite
- 5. Peracetic Acid

GOAL disrupt polysaccharide-lignin associations
Hydrolytic

- 1. Partial solubilization of hemicellulose
- 2. Above 5% NaOH some lignin and silica solubilized
- 3. Disruption of intermolecular hydrogen bonding of cellulose
- 4. Increased rate of fiber hydration
- 5. Increased rate of bacterial colonization
- 6. Decreased lag time

Van Soest, Berger

Oxidative

- 1. Reduction in cell wall lignin
- 2. Cleave glycosidic linkages of cell wall polysaccharides
- 3. Increase in soluble carbohydrate concentration
- 4. Usually more effective with dicots than monocots

Van Soest, Berger

Goal: Increase pH

- pH needs to be above 8
- Fermentation is not desired
- Acidifying process making treatment less effective
- Combination with ethanol byproducts for storage
  - DGS pH 3.0-3.5
- Storage vs ensiling

Use of chemical treatment to enhance digestibility

NaOH:
- Jared and Donefer, 1970
- Hogan and Weston, 1971
- Saxena et al., 1971
- Anderson and Ralston, 1973
- Klopfenstein and Koers, 1973
- Rounds and Klopfenstein, 1974
- Waller and Klopfenstein, 1975
- Todorov, 1975
- Garrett et al., 1976
- Rexen and Thomsen, 1976
- Chesson et al., 1981
- Wang et al. 2004

CaOH:
- Rounds and Klopfenstein, 1974
- Waller and Klopfenstein, 1975
- Waller et al., 1976
- Leosing et al., 1980

Digestibility

NaOH > CaO
NaOH + CaO = $\uparrow$NaOH

Use of chemical treatment to enhance digestibility

- Crystallinity is a highly ordered 3-dimensional structure which may impair digestibility.
  - For example, raw cotton fiber is highly crystalline cellulose and digests slowly.
  - When soaked in NaOH, the cotton fiber swells and becomes amorphous. Hydrogen bonding is reduced and rate and extent of cellulose digestion increase.
Know how. Know now.

Berger 2012 Review

**NaOH**
- 1. DM intake increased 22% when summarized 24 studies
- 2. Averaged over 32 studies, DM digestibility increased 30%
- 3. All diets > 60% treated residue

**Anhydrous**
- 1. DM intake increased 22% averaged over 21 treated crop residues
- 2. DM digestibility increased 15% averaged over 32 studies
- 3. Usually ~ 33% of the NH₃ is retained.
- 4. Temperature, water content, length of reaction time influences effectiveness

Current

**CaO**
- Quicklime
- Less caustic than other treatments
- Cost competitive
- Improvement of digestibility
- No detrimental impacts on fields receiving manure
- Need the dietary calcium anyway
- CaOH should work similar, but less heat, and need slightly more

Challenges

**NaOH**
- Cost of chemicals
- Na in manure
- Safety-handling
- Length of reaction time
- Storage
- Feasibility
- What about inclusion in finishing diets?

**CaO + H₂O**
Release of heat
- 2 parts water +1 part lime
- Solution will boil

Thermochemical
- Heat + releasing bonds

CaO (s) + H₂O ⇌ (l) Ca(OH)₂ (aq)
Shreck et al., 2011
- Optimize use of chemical treatments
  - Factors:
    - DM
    - Chemical
    - Reaction Length
    - Ambient Temperature
    - Forage type

Effects on Digestibility

Summary of in vitro work
- Chemical treatment, relative to control:
  - 3%CaO 2%NaOH: 15% unit increase in DMD
  - 4%CaO 1%NaOH: 14% unit increase in DMD
  - 5% CaO: 11% unit increase in DMD

- DM:
  - 35%: 1.25% reduction
  - 50%: optimum

- Temperature, relative to room temp (30°C)
  - 40°C: 1% unit increase

- 7 d treatment

Treating Stover-Step 1.
- Ground (Mighty Giant, Jones Mfg, Beemer, NE)
  - 3-in screen

Treating Stover-Step 2.
- CaO added at 5% (DM-basis) of forage

Treating Stover-Step 3.
- Granular CaO
  - Standard quicklime (1/4")
  - >98% purity
  - 71% Ca
  - $350/ton

Treating Stover-Step 4.
- Water added to equal 50% DM
Treating Stover-Step 5.  
- Bagged and stored for at least one week prior to feeding

**Table 1. Dietary treatments Exp 1101**  
<table>
<thead>
<tr>
<th>Ingredient, % of DM</th>
<th>Control</th>
<th>Wheat Straw</th>
<th>Corn Stover</th>
</tr>
</thead>
<tbody>
<tr>
<td>HMC</td>
<td>25.5</td>
<td>18.0</td>
<td>18.0</td>
</tr>
<tr>
<td>DRC</td>
<td>25.5</td>
<td>18.0</td>
<td>18.0</td>
</tr>
<tr>
<td>Stover-treated¹</td>
<td>5.0</td>
<td>20.0</td>
<td>20.0</td>
</tr>
<tr>
<td>Stover-not treated</td>
<td>4.0</td>
<td>40.0</td>
<td>40.0</td>
</tr>
<tr>
<td>WDGS</td>
<td>40.0</td>
<td>40.0</td>
<td>40.0</td>
</tr>
<tr>
<td>Straw-treated</td>
<td>—</td>
<td>20.0</td>
<td>—</td>
</tr>
<tr>
<td>Stover-treated</td>
<td>—</td>
<td>—</td>
<td>20.0</td>
</tr>
<tr>
<td>Cobs-native¹</td>
<td>3.3</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Wheat straw-native</td>
<td>3.3</td>
<td>—</td>
<td>20.0</td>
</tr>
<tr>
<td>Corn stover-native</td>
<td>3.3</td>
<td>—</td>
<td>20.0</td>
</tr>
<tr>
<td>Supplement²</td>
<td>4.0</td>
<td>4.0</td>
<td>4.0</td>
</tr>
</tbody>
</table>

¹Treated with 5% CaO and water added to 50% DM  
²Formulated to provide 360 mg/hd/d Rumensin and 90 mg/hd/d Tylan

15% units replacement

**Table 2. Diets**  
<table>
<thead>
<tr>
<th>Ingredient, % of DM</th>
<th>Control</th>
<th>Wheat Straw</th>
<th>Corn Stover</th>
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</thead>
<tbody>
<tr>
<td>DRC</td>
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<td>36.0</td>
<td>36.0</td>
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<tr>
<td>WDGS</td>
<td>40.0</td>
<td>40.0</td>
<td>40.0</td>
</tr>
<tr>
<td>Straw-treated</td>
<td>—</td>
<td>20.0</td>
<td>—</td>
</tr>
<tr>
<td>Stover-treated</td>
<td>—</td>
<td>—</td>
<td>20.0</td>
</tr>
<tr>
<td>Cobs-native¹</td>
<td>3.3</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Wheat straw-native</td>
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<td>—</td>
<td>20.0</td>
</tr>
<tr>
<td>Corn stover-native</td>
<td>3.3</td>
<td>—</td>
<td>20.0</td>
</tr>
<tr>
<td>Supplement²</td>
<td>4.0</td>
<td>4.0</td>
<td>4.0</td>
</tr>
</tbody>
</table>

¹20% cobs treated and native (data not shown)  
²Balanced for Ca:P

360 calf-feds- 822 lb  
15% units replacement
### Call-feds and yearlings

<table>
<thead>
<tr>
<th>Ingredient, % of DM</th>
<th>Control</th>
<th>Treated</th>
<th>Untreated</th>
<th>Treated</th>
<th>F-test</th>
</tr>
</thead>
<tbody>
<tr>
<td>HMC</td>
<td>25.5</td>
<td>18.0</td>
<td>18.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>DRC</td>
<td>25.5</td>
<td>18.0</td>
<td>18.0</td>
<td></td>
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</tr>
<tr>
<td>Stover-treated¹</td>
<td>—</td>
<td>20.0</td>
<td>—</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stover-not treated</td>
<td>5.0</td>
<td>—</td>
<td>20.0</td>
<td></td>
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<tr>
<td>MDGS</td>
<td>40.0</td>
<td>40.0</td>
<td>40.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Supplement²</td>
<td>4.0</td>
<td>4.0</td>
<td>4.0</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

¹Treated with 5% CaO and water added to 50% DM
²Formulated to provide 360 mg/hd/d Rumensin and 90 mg/hd/d Tylan

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### Carcass-adjusted performance - Call feds

**Call-feds** (n=192) fed from Nov-May, 8 pens/trt

<table>
<thead>
<tr>
<th>Item</th>
<th>Control</th>
<th>Treated</th>
<th>Native</th>
<th>F-test</th>
</tr>
</thead>
<tbody>
<tr>
<td>DMI, lb/d</td>
<td>22.4</td>
<td>22.4</td>
<td>22.9</td>
<td>0.42</td>
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<tr>
<td>ADG, lb</td>
<td>3.67</td>
<td>3.61</td>
<td>3.24</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>F:G</td>
<td>6.36</td>
<td>6.22</td>
<td>7.05</td>
<td>&lt;0.01</td>
</tr>
</tbody>
</table>

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### Carcass-adjusted performance - Yearlings

**Yearlings** (n=192) fed from June-Oct, 8 pens/trt

<table>
<thead>
<tr>
<th>Item</th>
<th>Control</th>
<th>Treated</th>
<th>Native</th>
<th>F-test</th>
</tr>
</thead>
<tbody>
<tr>
<td>DMI, lb/d</td>
<td>26.8</td>
<td>27.6</td>
<td>28.8</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>ADG, lb</td>
<td>4.18</td>
<td>4.04</td>
<td>3.77</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>F:G</td>
<td>6.42</td>
<td>6.85</td>
<td>7.65</td>
<td>&lt;0.01</td>
</tr>
</tbody>
</table>
Quality control

- Best to have original (untreated) sampled
- Measurements
  1. DM (water only)
  2. Chemical (Ca)
  3. Amount of NDF solubilized
  4. pH
  5. In vitro digestibility
- Lab energy calculation can be incorrect

<table>
<thead>
<tr>
<th></th>
<th>Untreated</th>
<th>Treated</th>
<th>% unit</th>
<th>% change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Summer-2010</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Straw</td>
<td>88.5</td>
<td>69.9</td>
<td>18.6</td>
<td>21.0</td>
</tr>
<tr>
<td>Stover</td>
<td>87.8</td>
<td>74.7</td>
<td>13.1</td>
<td>15.0</td>
</tr>
<tr>
<td>Winter-2011</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stover</td>
<td>77.9</td>
<td>65.8</td>
<td>12.1</td>
<td>18.1</td>
</tr>
<tr>
<td>Summer-2011</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Straw</td>
<td>82.9</td>
<td>71.6</td>
<td>11.3</td>
<td>13.6</td>
</tr>
<tr>
<td>Stover</td>
<td>82.2</td>
<td>71.0</td>
<td>11.2</td>
<td>13.7</td>
</tr>
</tbody>
</table>

pH

- Tends to decline over the feeding period

Energy value of treated residue

<table>
<thead>
<tr>
<th>Item</th>
<th>OM Digestibility</th>
<th>% Increase</th>
<th>% Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>In vitro</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Straw</td>
<td>27.9</td>
<td>43.0</td>
<td>68.4</td>
</tr>
<tr>
<td>Stover</td>
<td>24.3</td>
<td>34.9</td>
<td>51.7</td>
</tr>
<tr>
<td>In vivo, 25% inclusion</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Straw</td>
<td>69.3</td>
<td>78.4</td>
<td>52.4</td>
</tr>
<tr>
<td>Stover</td>
<td>66.3</td>
<td>78.4</td>
<td>73.2</td>
</tr>
</tbody>
</table>

Energy value-Relative to corn

- NRC (1996) using performance of control
  - NE\textsubscript{L} and NE\textsubscript{g} adjusters
- Assume:
  - MDGS: 112 TDN (125% energy value of corn)
  - WDGS: 118 TDN (130% energy value of corn)
  - Corn stover/wheat straw 41 TDN
  - Book values for corn
Summary

- Including 20% treated stalks/straw with 40% wet/modified DG:
  - Similar performance
  - Similar carcass
  - Lower diet cost

- We have future plans, need funding