Producing Quality Forages for Cattle and Sheep

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U.S. Dairy Forage Research Center
Madison, WI

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This talk will explore . . .

• Forage quality tests that effectively allocate forages to ruminant livestock
• What tests are needed?
• What do they mean?
• How to use them?
Ruminant Digestion End Products

- **Gases** – CO₂, CH₄, NH₄
- **Volatile Fatty Acids**
  - Acetic
  - Propionic
  - Butyric
- **Microbial Protein**
- **Undigested Feed**

SOURCE: Linn, James, G.; U of Minnesota
Effect of forage quality on 4% fat-corrected milk production at four concentrate levels

<table>
<thead>
<tr>
<th>% grain in ration</th>
<th>Prebloom</th>
<th>Early bloom</th>
<th>Mid bloom</th>
<th>Full bloom</th>
</tr>
</thead>
<tbody>
<tr>
<td>20%</td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>37%</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>54%</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>71%</td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

Source: Kawas et al., 1989
Understanding Forage Quality is Needed to:

- Improve profit
- Make improvements in animal performance
- Increase utilization of forage
Analytical Values Needed

- **Dry Matter**
- **Crude Protein**
- **Neutral Detergent Fiber**
- **Acid Detergent Fiber**
- **Acid Detergent Lignin**
- **Neutral Detergent Fiber Digestibility**
- **Ash**
Definition of Forage Quality

Analytical Terms

- **Dry matter (DM)** is the percentage of feed that is not water.
Definition of Forage Quality

Analytical Terms

- **Crude protein (CP)** is determined by measuring total nitrogen in a sample and multiplying by 6.25.
- It is a mix of true protein and non-protein nitrogen.
Definition of Forage Quality

Analytical Terms

- **Neutral detergent fiber (NDF)** is the percentage of fiber in a forage sample which is not soluble in a neutral detergent solution.
  - It is the residue left after boiling in neutral detergent solution.
  - It is called aNDF if amylase and sodium sulfite are used during the extraction.
Neutral detergent fiber analysis

Captures:
- cellulose
- hemicellulose
- lignin
- acid insoluble ash
- cutin

Releases:
- cell solubles
  - sugars
  - starch
  - fat
- protein
- NPN
- pectin
Neutral Detergent Fiber (NDF)

- Represents cell walls
- Partially digestible
- 100 - NDF = cell solubles
- NDF is inversely related to voluntary intake
Definition of Forage Quality

Analytical Terms

- **Acid detergent fiber (ADF)** is the percentage of fiber in a forage sample which is insoluble in a weak acid.

- It is the residue remaining after boiling a forage sample in acid detergent solution.
Acid detergent fiber analysis

Captures:
- cellulose
- lignin
- silica (insoluble ash)
- cutin

Releases:
- cell solubles
- hemicellulose

Producing Quality Forages for Cattle and Sheep
Acid Detergent Fiber (ADF)

- Represents cell wall minus hemicellulose
- Is inversely related to digestibility
Definition of Forage Quality

Analytical Terms

- **Lignin** – polymer of phenyl propane units
  - Gives strength to plant
  - Undigestible
  - Reduces digestion of fiber
Definition of Forage Quality

Analytical Terms

- **Ash** (also called total ash) is an estimate of the total mineral content; the residue remaining after burning a sample.

- Values above 6% for grasses or 8% for legumes usually indicate soil contamination of forage.

- Each 1% soil contamination is 1% less TDN of forage.

- Ash, ADF-ash and NDF-ash will be different values because ADF and NDF procedures remove some minerals.
Definition of Forage Quality

Analytical Terms

• **Neutral Detergent Fiber Digestibility** (NDFD) is the portion of Neutral Detergent Fiber lost during incubation with rumen fluid.

• Incubation times may be 24 to 48 hours.
Influence of NDF digestibility on forage digestibility

TDN = tdCP + (tdFA x 2.25) + (.75 x NDFD$_{48}$ x NDF) + tdNFC -7

<table>
<thead>
<tr>
<th></th>
<th>NDF</th>
<th>ADF</th>
<th>NDFD$_{48}$</th>
<th>TDN</th>
<th>DDM*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Forage A:</td>
<td>40</td>
<td>30</td>
<td>58</td>
<td>61.6</td>
<td>65.5</td>
</tr>
<tr>
<td>Forage B:</td>
<td>40</td>
<td>30</td>
<td>36</td>
<td>53.6</td>
<td>65.5</td>
</tr>
</tbody>
</table>

*DDM = 88.9 - 0.779(ADF)
Influence of NDF digestibility on dry matter intake

\[
d\text{Intake} = \text{base intake plus adjustment for dNDF} + [(\text{NDFD}-\text{average NDFD}) \times .374]
\]


<table>
<thead>
<tr>
<th></th>
<th>NDF</th>
<th>ADF</th>
<th>NDFD</th>
<th>d\text{Intake}</th>
<th>DMI*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Forage A</td>
<td>40</td>
<td>30</td>
<td>58</td>
<td>31.0</td>
<td>2.78% of BW</td>
</tr>
<tr>
<td>Forage B</td>
<td>40</td>
<td>30</td>
<td>36</td>
<td>22.8</td>
<td>2.78% of BW</td>
</tr>
</tbody>
</table>

*DMI = 120/NDF
## Adjusting DMI, Base TMR

<table>
<thead>
<tr>
<th>Ingredient</th>
<th>lb DM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alfalfa 20-30-40-58</td>
<td>25</td>
</tr>
<tr>
<td>Corn silage</td>
<td>6</td>
</tr>
<tr>
<td>HMC</td>
<td>20</td>
</tr>
<tr>
<td>Protein/mineral/vitamins</td>
<td>7</td>
</tr>
<tr>
<td>DMI</td>
<td>58</td>
</tr>
</tbody>
</table>

**NRC 2001 ration evaluation (110 lb milk)**
- NE allowable milk, lb: 93
- MP allowable milk, lb: 110
- NEI balance, Mcal: - 5.6
- TMR Nel, Mcal/lb: .70
<table>
<thead>
<tr>
<th>Ingredient</th>
<th>lb DM</th>
<th>Impact</th>
<th>Action steps</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alfalfa 20-30-40-58</td>
<td>25</td>
<td>TDN 61.6 -&gt; 53.6</td>
<td>• Change alfalfa TDN in ration program</td>
</tr>
<tr>
<td>Corn silage</td>
<td>6</td>
<td>dIntake 31.0 -&gt; 22.8</td>
<td>• Discount TMR intake</td>
</tr>
<tr>
<td>HMC</td>
<td>20</td>
<td></td>
<td>.374(58-36) = 8 lb</td>
</tr>
<tr>
<td>Protein/mineral/vitamins</td>
<td>7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>DMI</td>
<td>58</td>
<td></td>
<td></td>
</tr>
<tr>
<td>NRC 2001 ration evaluation</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NE allowable milk, lb</td>
<td>93</td>
<td></td>
<td></td>
</tr>
<tr>
<td>MP allowable milk, lb</td>
<td>110</td>
<td></td>
<td></td>
</tr>
<tr>
<td>NEI balance, Mcal</td>
<td>-5.6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>TMR Nel, Mcal/lb</td>
<td>.70</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### Adjusting DMI and TDN

<table>
<thead>
<tr>
<th></th>
<th>Base TMR 20-30-40-58</th>
<th>Adjusted TMR 20-30-40-36</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alfalfa</td>
<td>25</td>
<td>22</td>
</tr>
<tr>
<td>Corn silage</td>
<td>6</td>
<td>5</td>
</tr>
<tr>
<td>HMC</td>
<td>20</td>
<td>17</td>
</tr>
<tr>
<td>Protein/mineral/vitamins</td>
<td>7</td>
<td>6</td>
</tr>
<tr>
<td>DMI</td>
<td>58</td>
<td>50</td>
</tr>
<tr>
<td>NRC 2001 ration evaluation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>NE allowable milk, lb</td>
<td>93</td>
<td>83</td>
</tr>
<tr>
<td>MP allowable milk, lb</td>
<td>110</td>
<td>91</td>
</tr>
<tr>
<td>NE\text{\textsubscript{l}} balance, Mcal</td>
<td>- 5.6</td>
<td>-8.7</td>
</tr>
<tr>
<td>TMR NE\text{\textsubscript{l}}, Mcal/lb</td>
<td>.70</td>
<td>.73</td>
</tr>
</tbody>
</table>
Calculated Terms Needed

- Digestible Dry Matter
- Dry Matter Intake
- Relative Feed Value
- Relative Forage Quality
Definition of Forage Quality

Calculated Terms

- **Digestible Dry Matter (DDM)** is the portion in a forage that is digested by animals at a specified level of intake.

  - **Estimated by:**
    - measuring in vitro or in situ digestibility,
    - near infrared reflectance spectroscopy
    - calculated from % ADF (most common but not recommended).

  \[
  \% \text{ DDM} = 88.9 - (\% \text{ ADF} \times 0.779)
  \]

  \[
  \% \text{ DDM} = \% \text{ TDN}
  \]
Comparison of ADF to TDN for Alfalfa, 2003 Forage Superbowl

\[ y = -0.542x + 80.784 \]

\[ R^2 = 0.4365 \]
Definition of Forage Quality

Calculated Terms

- **Dry matter intake (DMI)** is an estimate of the relative amount of forage an animal will eat when only forage is fed.

\[
\text{DMI as a percent of body weight} = \frac{120}{\text{Forage NDF (\% of DM)}}
\]
Definition of Forage Quality

Calculated Terms

- **Relative Feed Value (RFV)** is an index which ranks legume and legume-grass forages by digestible dry matter intake potential.
Use of the RFV index

- Allocate forages to livestock
- Purchase hay
- Forage management evaluation

RFV index = \frac{\% \text{ DDM} \times \text{DMI}}{1.29}
Relative Feed Value (Current)

Intake Potential = 120/NDF

Digestible DM = 88.9 - (0.779 * ADF)

Constant = 1.29
Producing Quality Forages for Cattle and Sheep

Forage Composition - Alfalfa vs. Grass

**Midbloom Alfalfa**
- ADF, 30%
- Hemicellulose, 10%
- Cell Solubles, 60%

**Early Bloom Orchardgrass**
- ADF, 30%
- Hemicellulose, 30%
- Cell Solubles, 40%

**RFV 152**
- NDF, 40%
- Cell Solubles, 60%

**RFV 102**
- NDF, 60%
- Cell Solubles, 40%
Definition of Forage Quality

Calculated Terms

- **Relative Forage Quality (RFQ)** is an index which ranks legume, grass and legume-grass forages by digestible dry matter intake potential.
Definition of Forage Quality

Relative Forage Quality (RFQ) =

\[(\text{dIntake Potential} \times \text{dTDN}) / \text{Constant}\]

Same concept as RFV
✓ using NDF as in RFV
✓ but adding fiber digestibility
Summative Approach to Predicting TDN of Forages

- Uniform feed fractions will have predictable digestion coefficients

\[
\text{TDN}_{1-x} = \text{tdCP} + (\text{tdFA} \times 2.25) + \text{tdNDF} + \text{tdNFC} - 7
\]

+ A more accurate and robust way to estimate TDN of forages than ADF
- TDN values estimated by NRC(2001) are different than what we are used to.
Relative Forage Quality

Intake potential

\[ = \text{base intake plus adjustment for dNDF} \]
\[ = \text{base intake} + [(d\text{NDF}-\text{average } d\text{NDF}) \times 0.374] \]
\[ = (0.012/NDF) + (NDFD-45) \times 0.374 \times \frac{1350}{100} \]

From Oba and Allen, 1999, J Dairy Sci
Forage Composition - Alfalfa vs. Grass

Midbloom Alfalfa:
- NDF: 40%
- Cell Solubles: 60%
- Undigested: 22%
- Digestible fiber: 18%
- RFV: 152
- RFQ: 145

Early Bloom Orchardgrass:
- NDF: 60%
- Cell Solubles: 40%
- Undigested: 18%
- Digestible fiber: 42%
- RFV: 102
- RFQ: 141

Producing Quality Forages for Cattle and Sheep
Relative Forage Quality for Grasses

$$\text{TDN}_{\text{grass}} = (\text{NFC} \times .98) + (\text{CP} \times .87) + (\text{FA} \times .97 \times 2.25) + (\text{NDFn} \times \text{NDFDp}/100) - 10$$

Where \( \text{NDFDp} = 22.7 + .664 \times \text{NDFD} \)

$$\text{DMI}_{\text{Grass}} = -2.318 + 0.442 \times \text{CP} - 0.0100 \times \text{CP}^2 - 0.0638 \times \text{TDN} + 0.000922 \times \text{TDN}^2$$

$$+ 0.180 \times \text{ADF} - 0.00196 \times \text{ADF}^2 - 0.00529 \times \text{CP} \times \text{ADF}$$

Source: Moore and Undersander, 2002
Moore and Kunkle, 1999

Producing Quality Forages for Cattle and Sheep
Uses of Relative Forage Quality

- When to harvest
- Allocation of hay to animals
- Buying/selling hay
- Contracting for harvest with quality incentive
Producing Quality Forages for Cattle and Sheep

Comparison of RFV and RFQ for Hay, Haylage, and Baleage, 2002 Worlds Forage Superbowl

\[ y = 1.1446x - 32.224 \]

\[ R^2 = 0.8623 \]

RFV and RFQ same when digestibility is average
Forage Quality Needs of Animals

- Dairy, 1st trimester
  - Dairy Calf

- Dairy, last 200 days
  - Heifer, 3-12 month
  - Stocker cattle

- Heifer, 12-18 mo
  - Beef cow & calf

- Heifer, 18-24 mo
  - Dry cow

Producing Quality Forages for Cattle and Sheep
Forage Quality Needs of Animals

- Stocker cattle
- Growing lambs & kids
- Nursing mare
- Hard working horse
- Beef cow & calf
- Ewe with lamb
- Doe with kid
- Ewe/ Doe, not lactating
- Idle horse

Relative Forage Quality

Producing Quality Forages for Cattle and Sheep
## Protein Content of Forage

### Analytical Results of Four Hay Samples on a 100% Dry Matter Basis

<table>
<thead>
<tr>
<th>Component</th>
<th>158 Alfalfa/Orchard Grass</th>
<th>173 Alfalfa/Grass</th>
<th>225 Orchard Grass</th>
<th>178 Alfalfa/Grass</th>
</tr>
</thead>
<tbody>
<tr>
<td>Percent</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dry Matter (DM)</td>
<td>83.3</td>
<td>88.1</td>
<td>88.6</td>
<td>88.6</td>
</tr>
<tr>
<td>Crude Protein (CP)</td>
<td>16.9</td>
<td>8.4</td>
<td>7.9</td>
<td>9.6</td>
</tr>
<tr>
<td>ADF</td>
<td>45.5</td>
<td>40.7</td>
<td>44.4</td>
<td>41.2</td>
</tr>
<tr>
<td>NDF</td>
<td>56.0</td>
<td>58.7</td>
<td>68.4</td>
<td>57.9</td>
</tr>
<tr>
<td>NDFD</td>
<td>68.3</td>
<td>54.6</td>
<td>55.4</td>
<td>43.8</td>
</tr>
<tr>
<td>Phosphorus (P)</td>
<td>0.34</td>
<td>0.26</td>
<td>0.29</td>
<td>0.19</td>
</tr>
<tr>
<td>Potassium (K)</td>
<td>3.37</td>
<td>2.26</td>
<td>2.28</td>
<td>1.80</td>
</tr>
<tr>
<td>Calcium (Ca)</td>
<td>1.39</td>
<td>0.50</td>
<td>0.29</td>
<td>0.55</td>
</tr>
<tr>
<td>Magnesium (Mg)</td>
<td>0.33</td>
<td>0.22</td>
<td>0.23</td>
<td>0.22</td>
</tr>
</tbody>
</table>

Crude protein needs range from approximately 7% for mid-gestation mature dry cows to approximately 13% for beef cows nursing calves.
### NDF Content of Forage

<table>
<thead>
<tr>
<th>Component</th>
<th>Sample 1 (158) Alfalfa/Orchard Grass</th>
<th>Sample 2 (173) Alfalfa/Grass</th>
<th>Sample 3 (225) Orchard Grass</th>
<th>Sample 4 (178) Alfalfa/Grass</th>
</tr>
</thead>
<tbody>
<tr>
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<td>88.6</td>
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<td>0.33</td>
<td>0.22</td>
<td>0.23</td>
<td>0.22</td>
</tr>
</tbody>
</table>

- Range from 40% on early bloom legume hay to 72% on late cut grass hay.
- Maximum NDF DM content of the daily ration should be from 1.2 to 1.5 % of the cow's body weight.
- Higher quality forage results in more forage consumed.
- As NDF values increase, forage intake will decrease.
Corn Silage Report - UW Recommended

Report Number: 12346  Lab Number: 2  Sample Description: CS sample
Harvest date: 4/7/2006

<table>
<thead>
<tr>
<th>Item</th>
<th>Abbreviation</th>
<th>Unit</th>
<th>Unprocessed</th>
<th>Processed</th>
<th>Method</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dry Matter</td>
<td>DM</td>
<td>% as fed</td>
<td>35.64</td>
<td>35.54</td>
<td>WC</td>
</tr>
<tr>
<td>Moisture</td>
<td></td>
<td>% as fed</td>
<td>64.16</td>
<td>64.16</td>
<td>C</td>
</tr>
<tr>
<td>Protein Fractions</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Crude Protein</td>
<td>CP</td>
<td>% DM</td>
<td>8.09</td>
<td>8.09</td>
<td>NIR</td>
</tr>
<tr>
<td>Soluble Crude Protein</td>
<td>SCP</td>
<td>% CP</td>
<td>0.50</td>
<td>0.50</td>
<td>NR</td>
</tr>
<tr>
<td>Acid Detergent Fiber Crude Protein</td>
<td>ADF-CP</td>
<td>% DM</td>
<td>1.00</td>
<td>1.00</td>
<td>NDF</td>
</tr>
<tr>
<td>Neutral Detergent Fiber Crude Protein</td>
<td>NDF-CP</td>
<td>% DM</td>
<td>0.50</td>
<td>0.50</td>
<td>C</td>
</tr>
<tr>
<td>Heat Damaged Protein-Estimated</td>
<td></td>
<td>% DM</td>
<td>8.09</td>
<td>8.09</td>
<td>C</td>
</tr>
<tr>
<td>Fiber Fractions</td>
<td></td>
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<td></td>
<td></td>
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</tr>
<tr>
<td>Acid Detergent Fiber</td>
<td>ADF</td>
<td>% DM</td>
<td>23.34</td>
<td>23.34</td>
<td>NIR</td>
</tr>
<tr>
<td>Lignin Acid Detergent</td>
<td>ADL</td>
<td>% DM</td>
<td>4.66</td>
<td>4.66</td>
<td>NDF</td>
</tr>
<tr>
<td>Lignin, Acid Detergent</td>
<td>ADL</td>
<td>% NDF</td>
<td>11.28</td>
<td>11.28</td>
<td>C</td>
</tr>
<tr>
<td>Neutral Detergent Fiber Digestibility, 48 h, 1%NDF</td>
<td>NDF</td>
<td>% NDF</td>
<td>67.45</td>
<td>67.45</td>
<td>WC</td>
</tr>
<tr>
<td>Carbohydrates and Fats</td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Non Fiber Carbohydrate</td>
<td>NFC</td>
<td>% DM</td>
<td>45.48</td>
<td>45.48</td>
<td>C</td>
</tr>
<tr>
<td>Starch</td>
<td></td>
<td>% DM</td>
<td>26.80</td>
<td>26.80</td>
<td>NIR</td>
</tr>
<tr>
<td>Starch Digestibility, Predicted</td>
<td></td>
<td>% Starch</td>
<td>84.93</td>
<td>90.23</td>
<td>C</td>
</tr>
<tr>
<td>Non Starch NFC, Sugars + VFS</td>
<td></td>
<td>% DM</td>
<td>15.00</td>
<td>15.00</td>
<td>C</td>
</tr>
<tr>
<td>Fat</td>
<td></td>
<td></td>
<td>2.83</td>
<td>2.83</td>
<td>NIR</td>
</tr>
<tr>
<td>pH</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>NA</td>
</tr>
</tbody>
</table>

Energy Calculations: Schriber/Shearer

<table>
<thead>
<tr>
<th>Item</th>
<th>Abbreviation</th>
<th>Unit</th>
<th>Unprocessed</th>
<th>Processed</th>
<th>Method</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total digestible nutrients, IX</td>
<td>TDN</td>
<td>% DM</td>
<td>67.34</td>
<td>68.76</td>
<td>C</td>
</tr>
<tr>
<td>Net Energy Lactation, 3X</td>
<td>NEtL</td>
<td>Mcats/lb</td>
<td>0.63</td>
<td>0.65</td>
<td>C</td>
</tr>
<tr>
<td>Net Energy Maintenance</td>
<td>NEm</td>
<td>Mcats/lb</td>
<td>0.75</td>
<td>0.77</td>
<td>C</td>
</tr>
<tr>
<td>Net Energy Gains</td>
<td>NEg</td>
<td>Mcats/lb</td>
<td>0.47</td>
<td>0.49</td>
<td>C</td>
</tr>
<tr>
<td>Metabolizable Energy</td>
<td>ME</td>
<td>Mcats/lb</td>
<td>1.16</td>
<td>1.18</td>
<td>C</td>
</tr>
<tr>
<td>Milk/Ten</td>
<td>lbs</td>
<td></td>
<td>2.964</td>
<td>3.019</td>
<td>C</td>
</tr>
</tbody>
</table>

Macro Minerals

<table>
<thead>
<tr>
<th>Nutrient</th>
<th>Abbreviation</th>
<th>Unit</th>
<th>Unprocessed</th>
<th>Processed</th>
<th>Method</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phosphorus</td>
<td>P</td>
<td>% DM</td>
<td>0.20</td>
<td>0.20</td>
<td>WC</td>
</tr>
<tr>
<td>Calcium</td>
<td>Ca</td>
<td>% DM</td>
<td>0.43</td>
<td>0.43</td>
<td>C</td>
</tr>
<tr>
<td>Magnesium</td>
<td>Mg</td>
<td>% DM</td>
<td>1.55</td>
<td>1.55</td>
<td>NDF</td>
</tr>
<tr>
<td>Sodium</td>
<td>Na</td>
<td>% DM</td>
<td>0.23</td>
<td>0.23</td>
<td>NDF</td>
</tr>
<tr>
<td>Chloride</td>
<td>Cl</td>
<td>% DM</td>
<td>0.20</td>
<td>0.20</td>
<td>WC</td>
</tr>
</tbody>
</table>

Micro Minerals

<table>
<thead>
<tr>
<th>Nutrient</th>
<th>Abbreviation</th>
<th>Unit</th>
<th>Unprocessed</th>
<th>Processed</th>
<th>Method</th>
</tr>
</thead>
<tbody>
<tr>
<td>Iron</td>
<td>Fe</td>
<td>ppm</td>
<td>0.63</td>
<td>0.65</td>
<td>C</td>
</tr>
<tr>
<td>Zinc</td>
<td>Zn</td>
<td>ppm</td>
<td>0.75</td>
<td>0.77</td>
<td>C</td>
</tr>
<tr>
<td>Copper</td>
<td>Cu</td>
<td>ppm</td>
<td>0.47</td>
<td>0.49</td>
<td>C</td>
</tr>
</tbody>
</table>

Methods used for these analyses can be found at http://uwlab.soils.wisc.edu/procedures.htm

CLIENT COPY
Ruminant Digestion
End Products

Gases – CO₂, CH₄, NH₄

Volatile Fatty Acids
Acetic
Propionic
Butyric

Microbial Protein
Undigested Feed

SOURCE: Linn, James, G.; U of Minnesota
The Sampling Dilemma

Producing Quality Forages for Cattle and Sheep
Variation in RFV--Lot 6

Ave.=131
Standardized Sampling Guidelines
For Small Bales:

- **Identify** a single lot of hay (<200 tons)
- **Choose an appropriate, sharp coring device** (3/8’’ - 3/4’’)
- **Sample at random** (don't avoid bales)
- **Take enough cores to represent a lot** (>20)
- **Use proper technique** (90° angle, 18”-24”)
- **Handle samples correctly** (plastic bags, heat)
- **Appropriate size**: not too big, not too small (1/2 lb)
- **Only split samples after grinding to test labs**
Reducing Analysis Error

- Only send results to National Forage Testing Association certified laboratories

http://www.foragetesting.org
Questions?