Understanding Forage Yield, Nutritive Value and Quality

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Ruminant Use of Forage Crops

- Microbial breakdown of fiber in digestive tract
  - Cellulose
  - Hemicellulose
What is Forage Quality

- Ultimate measure is animal performance
- Other factors include:
  - Nutritional value
  - Voluntary intake
  - Anti-quality constituents
What is Forage Quality

Plant/Animal Interactions
  Balance of forage nutrients
  Extent of digestion
  Rate of digestion
  Rate of passage
  Utilization of digested nutrients
  Availability of forage
  Palatability of forage
  Antiquality effects
  Interactions with feed supplements

Animal Performance
(milk production, weight gain etc.)

Collins and Fritz, 2003
General Forage Composition

- Cell contents
  - Proteins
  - Organic acids
  - Lipids
  - Starch
  - Sugars
  - 90-100% digestible

- Cell walls
  - Structural carbohydrates
    - Cellulose
    - Hemicellulose
  - Lignin
  - Cutin
  - Silica
  - Pectin

- Variable digestibility
- Major determinants of animal performance on forage diets
Cell Wall Carbohydrates

- **Cellulose**
  - Glucose connected together
  - Interlinked to form microfibrils
  - Slowly digested

- **Hemicellulose**
  - Multiple carbohydrate types connected
  - 3 to 4 times higher in grasses than legumes
  - Variably digested

- **Pectins**
  - Found in middle lamella and primary cell wall
  - Glue cells together
  - Higher in legumes than grasses
Lignin

- Phenolic compound
- Adds rigidity to plant
- Interspersed in cellulose
- Indigestible
- Suppresses digestibility of other cell wall material
- 3-12% lignin in forage crops
- Higher in legumes than grasses
The Cell Wall

Collins and Fritz, 2003
The Cell Wall

Model of a primary cell wall. The plant cell wall is organized into microfibrils, each measuring about 3 to 6 nm in diameter and 136 glucan chains having thousands of glucose residues. Like steel girders stabilizing a structure, the primary cell wall’s mechanical strength comes from the microfibril scaffold. A microfibril’s paracrystalline (amorphous) core is surrounded by a branched polymer network containing (5-carbon) and (6-carbon) sugars. In addition to these individual microfibrils, the secondary cell wall Schneider et al. (1992) 2004 AAAS
Forage Nitrogen

- **Protein N**
  - 60-80% of total N in fresh forages
  - Generally, legumes > cool-season grasses > warm-season grasses
  - Digestible protein N
  - Indigestible protein N

- **Nonprotein N**
  - 20-40% of total N in fresh forages
  - Nitrates
  - Free amino acids
  - Small peptides

- **Crude protein**
  - Includes protein N and nonprotein N
  - Equals total N x 6.25
Factors Affecting Forage Quality

- Forage species
- Stage of maturity
- Harvest conditions
- Temperature
- Moisture
- Soil fertility
- Cultivar
- Others

Plant anatomy and morphology
Plant Anatomy and Morphology

- Affected by other management factors and species
- Leaves higher quality than stems
- Cell types impact quality
- Leaf to stem ratio

Collins and Fritz, 2003
Generally, legume > cool-season grass > warm-season grass

- Dairy cow, 57 lb milk/day
- 500 lb Steer, 2.5 lb daily gain
- Mature brood cow, average milking ability
- Dry, beef brood cow (2nd trimester)

Collins and Fritz, 2003
# Plant Species

**Table 16.1.** Tissue types in leaf cross sections of a warm-season (bermudagrass) and a cool-season (tall fescue) forage grass

<table>
<thead>
<tr>
<th>Cell type</th>
<th>Bermudagrass</th>
<th>Tall fescue</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vascular bundles</td>
<td>37</td>
<td>11</td>
</tr>
<tr>
<td>Epidermis</td>
<td>26</td>
<td>19</td>
</tr>
<tr>
<td>Sclerenchyma</td>
<td>10</td>
<td>7</td>
</tr>
<tr>
<td>Mesophyll</td>
<td>27</td>
<td>62</td>
</tr>
</tbody>
</table>

*Source:* Akin and Burdick 1975.

**Table 16.2.** Forage quality of alfalfa and timothy components of a mixture

<table>
<thead>
<tr>
<th>Species</th>
<th>Crude protein (%)</th>
<th>NDF (%)</th>
<th>ADF (%)</th>
<th>Cell wall digestibility&lt;sup&gt;a&lt;/sup&gt;</th>
<th>Cell wall digestion rate&lt;sup&gt;b&lt;/sup&gt; (%/hour)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alfalfa</td>
<td>15.8</td>
<td>49</td>
<td>34</td>
<td>46</td>
<td>5.3</td>
</tr>
<tr>
<td>Timothy</td>
<td>9.5</td>
<td>66</td>
<td>38</td>
<td>57</td>
<td>2.3</td>
</tr>
</tbody>
</table>


<sup>a</sup>The percentage of the sample NDF lost during 72 hours of incubation in a rumen fluid-buffer solution mixture.

<sup>b</sup>The percentage of the digestible cell wall material disappearing during each hour of incubation.
Stage of Maturity

- Quality declines as forages mature
- Leaf:Stem ratio declines with maturity
Miscellaneous Forage Quality Factors

- Grass/legume mixtures
- Fertilization (grasses mainly)
  - Possibly increase quality
  - Increase yield
- Environment
  - Temperature
  - Cutting time during the day
- Cultivar
Evaluating Forages for Quality
Forage quality needs of cattle and horses

- dairy, 1st trimester
dairy, last 200 days
heifer, 3-12 months
stoker cattle

- nursing mare
hard-working horse

- heifer, 12-18 months
beef cow with calf

- brood mare
working horse

- heifer, 18-24 months
dry cow
idle horse

Adapted from Undersander et al., 1994
Interpreting Forage Test Results

- CP
- ADF
- RFV
- DMI
- TDN
- Minerals
- Moisture
- DM
- Adj.-CP
- Energy
- NDF
- DDM
- ADIN
- ADF-CP

Energy
Interpreting Forage Test Results

Definitions

**Dry matter (DM):** Amount of plant sample remaining after all water has been removed. USE THESE VALUES.

**Crude protein (CP):** Total nitrogen multiplied by 6.25. Includes both true protein and nonprotein nitrogen.

**Neutral detergent fiber (NDF):** Percentage of fiber or cell walls in a feed, inversely related to intake, and only partially digestible. Made up primarily of hemicellulose, cellulose, and lignin.

**Acid detergent fiber (ADF):** Percentage of highly indigestible and slowly digestible plant material. Composed primarily of cellulose and lignin.
Digestible dry matter (DDM): Percentage of sample which is digestible to an animal. Often calculated from ADF.

Dry matter intake (DMI): An estimate of the amount of forage an animal will consume if fed entirely the tested forage. Commonly calculated from NDF.

Relative feed value (RFV): An index used to compare like forages. RFV is calculated from DDM and DMI. Full-bloom alfalfa typifies a forage with an RFV of 100.
RFV Example Calculation

Equations

\[ DDM = 88.9 - (0.779 \times \%ADF) \]
\[ DMI = \frac{120}{\%NDF} \]
\[ RFV = \frac{DDM \times DMI}{1.29} \]

Example (assume 35% ADF and 43% NDF)

\[ DDM = 61.6\% \]
\[ DMI = 2.79\% \]
\[ RFV = 134 \]
Use/Abuse of RFV

- Used in hay marketing (buying and selling)
- Should be used to compare like forages
# Forage Quality Standards

Quality standards for legumes, legume-grass mixtures, and grasses.

<table>
<thead>
<tr>
<th>Quality Standard</th>
<th>CP</th>
<th>ADF</th>
<th>NDF</th>
<th>RFV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prime</td>
<td>&gt;19</td>
<td>&lt;31</td>
<td>&lt;40</td>
<td>&gt;151</td>
</tr>
<tr>
<td>1</td>
<td>17-19</td>
<td>31-35</td>
<td>40-46</td>
<td>151-125</td>
</tr>
<tr>
<td>2</td>
<td>14-16</td>
<td>36-40</td>
<td>47-53</td>
<td>124-103</td>
</tr>
<tr>
<td>3</td>
<td>11-13</td>
<td>41-42</td>
<td>54-60</td>
<td>102-87</td>
</tr>
<tr>
<td>4</td>
<td>8-10</td>
<td>43-45</td>
<td>61-65</td>
<td>86-75</td>
</tr>
<tr>
<td>5</td>
<td>&lt;8</td>
<td>&gt;45</td>
<td>&gt;65</td>
<td>&lt;75</td>
</tr>
</tbody>
</table>
# Proposed Hay Testing Guidelines

**Alfalfa and alfalfa/grass hay**

<table>
<thead>
<tr>
<th>Quality Standard</th>
<th>ADF % of DM</th>
<th>RFV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Supreme</td>
<td>&lt; 27</td>
<td>&gt; 180</td>
</tr>
<tr>
<td>Premium</td>
<td>27-30</td>
<td>150-180</td>
</tr>
<tr>
<td>Good</td>
<td>30-32</td>
<td>125-150</td>
</tr>
<tr>
<td>Fair</td>
<td>32-35</td>
<td>100-125</td>
</tr>
<tr>
<td>Low</td>
<td>&gt; 35</td>
<td>&lt; 100</td>
</tr>
</tbody>
</table>
# Proposed Hay Testing Guidelines

<table>
<thead>
<tr>
<th>Grass hay</th>
<th>Quality Standard</th>
<th>CP (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Premium</td>
<td>&gt; 13</td>
<td></td>
</tr>
<tr>
<td>Good</td>
<td>9-13</td>
<td></td>
</tr>
<tr>
<td>Fair</td>
<td>5-9</td>
<td></td>
</tr>
<tr>
<td>Low</td>
<td>&lt; 5</td>
<td></td>
</tr>
</tbody>
</table>
## Example Comparison of Old Standards and New Guidelines

<table>
<thead>
<tr>
<th>Quality meas.</th>
<th>Haylage</th>
<th>Hay</th>
<th>Limpograss</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Moisture (%)</strong></td>
<td>27.8</td>
<td>10.8</td>
<td>11.3</td>
</tr>
<tr>
<td><strong>CP (%)</strong></td>
<td>20.2</td>
<td>18.7</td>
<td>15.5</td>
</tr>
<tr>
<td><strong>ADF (%)</strong></td>
<td>57.5</td>
<td>30.7</td>
<td>37.1</td>
</tr>
<tr>
<td><strong>NDF (%)</strong></td>
<td>60.6</td>
<td>39.3</td>
<td>59.0</td>
</tr>
<tr>
<td><strong>DDM (%)</strong></td>
<td>44.0</td>
<td>65.0</td>
<td>60.0</td>
</tr>
<tr>
<td><strong>DMI (%)</strong></td>
<td>2.0</td>
<td>3.1</td>
<td>2.0</td>
</tr>
<tr>
<td><strong>RFV</strong></td>
<td>67</td>
<td>154</td>
<td>95</td>
</tr>
<tr>
<td><strong>AFGC std.</strong></td>
<td>Std. 5</td>
<td>Prime</td>
<td>Std. 3</td>
</tr>
<tr>
<td><strong>New guide</strong></td>
<td>Low</td>
<td>Premium</td>
<td>Premium</td>
</tr>
</tbody>
</table>
Hay Sampling Demonstration
Sampling

- Representative Sample
- Results Only as Good as Sample
What Was Examined:

- 7 ‘Lots’ of hay with a wide range of forage quality (smaller than normal, still ‘lots’)
- Within Bale Variation--how much is there?
- Does it matter how many cores are taken?
- Why not a grab sample?
- Why not just 2-3 cores?
- Why not mix hay lots
Hay Sampling Demonstration: 7 Hay Lots

- **Lot 1**: 1999 Fourth Cut Excellent Quality 1,000 lb. Bales
- **Lot 2**: 1999 First Cut Rain-Damaged Hay 1,000 lb. bales
- **Lot 3**: 2000 First Cut Hay Excellent Quality 80 lb. bales
- **Lot 4**: 1999 Third Cut Medium Quality 80 lb. bales
- **Lot 5**: 2000 First Cut Good Quality 1,000 lb. bales
- **Lot 6**: 1999 Third Cut w/Bleach 1,000 lb. bales
- **Lot 7**: 2000 First Cut 700 lb. Round Bales
Crude protein (%) determination using 20-, 3-, and 1-core samples or a grab sample from 7 hay lots.

<table>
<thead>
<tr>
<th>Hay Lot</th>
<th>20 Cores</th>
<th>3 Cores</th>
<th>1 Core</th>
<th>Grab</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>21.6</td>
<td>21.5</td>
<td>22.0</td>
<td>20.0</td>
</tr>
<tr>
<td>2</td>
<td>20.4</td>
<td>21.5</td>
<td>22.2</td>
<td>17.0</td>
</tr>
<tr>
<td>3</td>
<td>18.9</td>
<td>19.9</td>
<td>20.4</td>
<td>17.6</td>
</tr>
<tr>
<td>4</td>
<td>19.0</td>
<td>20.8</td>
<td>19.7</td>
<td>19.0</td>
</tr>
<tr>
<td>5</td>
<td>19.4</td>
<td>18.7</td>
<td>18.5</td>
<td>15.5</td>
</tr>
<tr>
<td>6</td>
<td>20.1</td>
<td>21.5</td>
<td>21.8</td>
<td>17.3</td>
</tr>
<tr>
<td>7</td>
<td>19.9</td>
<td>18.9</td>
<td>19.1</td>
<td>15.1</td>
</tr>
<tr>
<td>Average</td>
<td>19.9</td>
<td>20.5</td>
<td>20.5</td>
<td>17.5</td>
</tr>
</tbody>
</table>
## Hay Sampling Demonstration: ADF

Acid detergent fiber (%) determination using a 20-, 3-, or 1-core sample or a grab sample from 7 lots of hay.

<table>
<thead>
<tr>
<th>Hay Lot</th>
<th>20 Cores</th>
<th>3 Cores</th>
<th>1 Core</th>
<th>Grab</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>22.5</td>
<td>23.8</td>
<td>23.5</td>
<td>25.9</td>
</tr>
<tr>
<td>2</td>
<td>42.7</td>
<td>41.4</td>
<td>42.4</td>
<td>47.5</td>
</tr>
<tr>
<td>3</td>
<td>31.9</td>
<td>31.0</td>
<td>30.7</td>
<td>34.1</td>
</tr>
<tr>
<td>4</td>
<td>38.3</td>
<td>36.5</td>
<td>36.1</td>
<td>37.4</td>
</tr>
<tr>
<td>5</td>
<td>30.6</td>
<td>29.1</td>
<td>32.5</td>
<td>34.2</td>
</tr>
<tr>
<td>6</td>
<td>35.2</td>
<td>34.1</td>
<td>33.3</td>
<td>37.9</td>
</tr>
<tr>
<td>7</td>
<td>36.3</td>
<td>36.8</td>
<td>36.7</td>
<td>42.1</td>
</tr>
</tbody>
</table>

| Average | 33.9     | 33.2    | 33.6   | 37.0  |
# Hay Sampling Demonstration: NDF

Neutral detergent fiber (%) determination using a 20-, 3-, or 1-core sample or a grab sample from 7 hay lots.

<table>
<thead>
<tr>
<th>Hay Lot</th>
<th>20 Cores</th>
<th>3 Cores</th>
<th>1 Core</th>
<th>Grab</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>29.8</td>
<td>30.8</td>
<td>31.0</td>
<td>33.2</td>
</tr>
<tr>
<td>2</td>
<td>55.8</td>
<td>54.3</td>
<td>56.4</td>
<td>60.7</td>
</tr>
<tr>
<td>3</td>
<td>37.8</td>
<td>37.1</td>
<td>37.7</td>
<td>40.7</td>
</tr>
<tr>
<td>4</td>
<td>47.4</td>
<td>47.3</td>
<td>45.7</td>
<td>45.4</td>
</tr>
<tr>
<td>5</td>
<td>36.4</td>
<td>35.6</td>
<td>38.8</td>
<td>40.4</td>
</tr>
<tr>
<td>6</td>
<td>43.6</td>
<td>42.4</td>
<td>41.2</td>
<td>48.1</td>
</tr>
<tr>
<td>7</td>
<td>44.2</td>
<td>45.2</td>
<td>44.2</td>
<td>48.8</td>
</tr>
<tr>
<td><strong>Average</strong></td>
<td><strong>42.1</strong></td>
<td><strong>41.8</strong></td>
<td><strong>42.1</strong></td>
<td><strong>45.3</strong></td>
</tr>
</tbody>
</table>
### Hay Sampling Demonstration: RFV

Relative feed value determination using a 20-, 3-, or 1-core sample or a grab sample from 7 hay lots.

<table>
<thead>
<tr>
<th>Hay Lot</th>
<th>20 Cores</th>
<th>3 Cores</th>
<th>1 Core</th>
<th>Grab</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>223</td>
<td>213</td>
<td>212</td>
<td>192</td>
</tr>
<tr>
<td>2</td>
<td>93</td>
<td>97</td>
<td>92</td>
<td>80</td>
</tr>
<tr>
<td>3</td>
<td>158</td>
<td>163</td>
<td>160</td>
<td>143</td>
</tr>
<tr>
<td>4</td>
<td>116</td>
<td>119</td>
<td>124</td>
<td>123</td>
</tr>
<tr>
<td>5</td>
<td>167</td>
<td>173</td>
<td>153</td>
<td>143</td>
</tr>
<tr>
<td>6</td>
<td>131</td>
<td>137</td>
<td>142</td>
<td>115</td>
</tr>
<tr>
<td>7</td>
<td>128</td>
<td>124</td>
<td>127</td>
<td>107</td>
</tr>
<tr>
<td><strong>Average</strong></td>
<td><strong>145</strong></td>
<td><strong>144</strong></td>
<td><strong>146</strong></td>
<td><strong>129</strong></td>
</tr>
</tbody>
</table>
Variation in CP by core number--Lot 5

Average=19.4
Variation in ADF by core number--Lot 5

Average = 30.5
Variation in RFV by core number--Lot 5

Average = 167
Sampling locations in large square bales
Standardized Sampling Guidelines

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