Have You Kept Pace With Forage Testing Options?

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Dairy Forage Seminars

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Madison, WI
Talking points . . .

- Forage Tests 30 Years Ago
- Standardize fiber analyses
- Addition of *in vitro* NDF digestibility
- Add ash to testing package
- Evolution of RFV and RFQ index
- New Tests – Diagnostic tools
Forage Tests 30 Years Ago

- Routine tests: Crude protein and crude fiber
- Crude fiber under estimated high quality forage and over estimated low quality forage
- New test - fiber analyses system (ADF, NDF & ADL)

Have You Kept Pace...
Forage Tests 30 Years Ago

- Forage quality of alfalfa hay – too low to support high milk production
- Routine use of forage testing limited
Effect of forage quality on 4% fat-corrected milk production at four concentrate levels

Source: Kawas et al., 1989
Standardize fiber analyses

- Mertens obtained AOAC approved method aNDF
- National Forage Testing Association established proficiency testing program (DM, CP, ADF, aNDF)
- Implementation of Near Infrared Reflectance Spectroscopy (NIRS)
Forage Quality: Terms and Definitions

Apparatus for Fiber Analysis

Refluxing Apparatus
- Cold water line
- Glass reflux condenser
- Ceramic plates with heating coil

Filtering Manifold
- Hot water
- 50 ml sintered glass crucibles
- Vacuum line
Standardize Forage Testing

- National Forage testing Association, www.foragetesting.org
Forage Testing

- **Before 1970** - protein, crude fiber, and minerals
- **During 1970’s** – introduction of detergent fiber system
- **1976** – Norris et al. USDA-ARS introduced Near Infrared Reflectance Spectroscopy (NIRS)
Near Infrared Reflectance Spectroscopy

- **USDA-ARS NIRS Network**
  - 1978 - 1989

- **USDA-CSREES Grants, 1984**

  Penn State University
  Richard Adams

  University of Minn.
  Jim Linn and Neal Martin

  University of Wis.
  Dwayne Rohweder and Terry Howard
Talking points . . .

- Forage Tests 30 Years Ago
- Standardize fiber analyses
- Addition of *in vitro* NDF digestibility
Comparison of ADF to *in vitro* digestibility of alfalfa

**SOURCE:** Undersander, Dan, UW Extension

**Equation:**

\[ R^2 = 0.5458 \]
Definition of Forage Quality

- **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.
- dNDF is expressed as percent of dry matter.
- NDFD is expressed as percent of NDF.
Add Ash to Test Package

- **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.
RFV and RFQ index

- 30 years ago we needed an index that estimated potential dry matter intake of forages fed to high producing dairy cows
- AFGC Hay Marketing Task Force proposed Relative Feed Value Index – National Alfalfa Hay Marketing Task Force Adopted RFV index using ADF & NDF to predict digestibility and intake
Change from RFV to RFQ

- Fiber digestibility varies
- Prediction of *in vivo* digestibility from linear regression equation does not fit samples outside data set
- Need to use summative equation to predict energy to improve accuracy of prediction

*Have You Kept Pace...*
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.
Definition of Forage Quality

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

\[(d\text{Intake Potential} \times d\text{TDN}) / \text{Constant}\]

Same concept as RFV
✓ using NDF as in RFV
✓ but in vitro fiber digestibility test
Forage Composition - Alfalfa vs. Grass

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

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

NDF, 40%
- Cell Solubles, 60%

RFV 152
RFV 102

Forage Quality: Terms and Definitions
Forage Composition - Alfalfa vs. Grass

Midbloom Alfalfa
- NDF, 40%
- Cell Solubles, 60%

Early Bloom Orchardgrass
- NDF, 60%
- Cell Solubles, 40%

Digestible fiber, 18%
Undigested, 22%
Cell Solubles, 60%

Digestible fiber, 42%
Cell Solubles, 40%

Forage Quality: Terms and Definitions

RFV 152
RFQ 145

RFV 102
RFQ 141
Relative Forage Quality

Intake potential

= base intake plus adjustment for dNDF
= base intake + [(dNDF-average dNDF) \( \times \) .374]
= \( \frac{0.012}{\text{NDF}} \) + (\( \text{NDFD-45} \) \( \times \) 0.374 \( \times \) 1350/100

*From Oba and Allen, 1999, J Dairy Sci*
Relative Forage Quality for Grasses

\[
\text{TDN}_{\text{grass}} = (\text{NFC} \times 0.98) + (\text{CP} \times 0.87) + (\text{FA} \times 0.97 \times 2.25) + \left(\frac{\text{NDFn} \times \text{NDFDp}}{100}\right) - 10
\]

Where \( \text{NDFDp} = 22.7 + 0.664 \times \text{NDFD} \)

\[
\text{DMI}_{\text{Grass}} = -2.318 + 0.442 \times \text{CP} - 0.0100 \times \text{CP}^2 - 0.0638 \times \text{TDN} + 0.000922 \times \text{TDN}^2 + 0.180 \times \text{ADF} - 0.00196 \times \text{ADF}^2 - 0.00529 \times \text{CP} \times \text{ADF}
\]

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

Forage Quality: Terms and Definitions
Uses of Relative Forage Quality

- When to harvest
- Allocation of hay to animals
- Buying/selling hay
- Contracting for harvest with quality incentive
New Tests – Diagnostic Tools

• Improved NDFD methods
• Protein and starch analyses
• Fermentation profiles
• Gas fermentation techniques in rumen-fluid to estimate rates of fermentation of carbohydrate pools
## Repeatability & Reproducibility

<table>
<thead>
<tr>
<th>Sample</th>
<th>Grand Mean 30 h NDFD Range</th>
<th>95% Probability Limits</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alfalfa</td>
<td>39.1 - 58.5</td>
<td>9.5</td>
</tr>
<tr>
<td>Corn Silage</td>
<td>43.8 - 62.6</td>
<td>10.7</td>
</tr>
<tr>
<td>Grass</td>
<td>33.4 - 73.9</td>
<td>8.7</td>
</tr>
</tbody>
</table>

Hall and Mertens, 2012
New Tests – Diagnostic Tools

Dr. David Combs and Rock River Lab presents:

A New Analysis for Total Tract NDFD and Use in a Ration Evaluator

Have You Kept Pace...
### New Tests – Diagnostic Tools

<table>
<thead>
<tr>
<th></th>
<th>TTNDFD, %</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Legumes</strong></td>
<td></td>
</tr>
</tbody>
</table>
| In vivo lit review  
(Goeser’s Ph.D)  
n=20 studies, 64 treatments | 47.3 |
| TTNDFD predicted with Standardized In vitro NDFD method  
(n=978 samples) | 46.7 |
| **Corn silage** |           |
| In vivo lit review  
(Goeser’s Ph.D)  
n=25 studies, 81 treatments | 40.2 |
| TTNDFD predicted with Standardized In vitro NDFD method  
(n=996 samples) | 40.0 |

Have You Kept Pace...
## New Tests – Diagnostic Tools

### Observed in vivo TTNDFD vs Lab-Predicted TTNDFD

<table>
<thead>
<tr>
<th></th>
<th>Legumes</th>
<th>Corn Silage</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>In vivo studies</td>
<td>In vivo studies</td>
</tr>
<tr>
<td><strong>Mean</strong></td>
<td>47.3</td>
<td>40.2</td>
</tr>
<tr>
<td><strong>Median</strong></td>
<td>47.5</td>
<td>41.1</td>
</tr>
<tr>
<td><strong>Range</strong></td>
<td>31-66</td>
<td>20-59</td>
</tr>
<tr>
<td><strong>St. Deviation</strong></td>
<td>8.1</td>
<td>8.8</td>
</tr>
<tr>
<td><strong>N</strong></td>
<td>64 treatment averages 20 trials</td>
<td>81 treatment averages 25 trials</td>
</tr>
</tbody>
</table>

Have You Kept Pace...
New Tests – Diagnostic Tools

TTNDFD

Total tract *in vivo* NDF digestibility predicted from the *in vitro* values

*TTNDFD integrates:*
*Amount of diet fiber…*
*Rate of ruminal fiber digestion… and*
*Rate of Passage of fiber…*

Allow comparisons across forage types and rations
Can be verified with direct measurements of digestibility

Have You Kept Pace...
Silage Fermentation Analysis...

**Crop factors**
- Moisture content
- Buffering capacity
- Sugar content

**Management factors**
- Packing speed
- Silage pack density
- Type of additive used
- Chop length
- Silo management during storage
- Silo management during feedout

Use FA to quantitatively explain poor silage nutritive value or low intakes *not to balance diets for cattle*
## Fermentation End Products

<table>
<thead>
<tr>
<th>End Product</th>
<th>Legume silage (30-40 %)$^1$</th>
<th>Legume silage (45-55 %)$^1$</th>
<th>Grass silage (30-35 %)$^1$</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH</td>
<td>4.3-4.7</td>
<td>4.7-5.0</td>
<td>4.3-4.7</td>
</tr>
<tr>
<td>Lactic acid, %</td>
<td>7-8</td>
<td>2-4</td>
<td>6-10</td>
</tr>
<tr>
<td>Acetic acid, %</td>
<td>2-3</td>
<td>0.5-2.0</td>
<td>1-3</td>
</tr>
<tr>
<td>Propionic acid, %</td>
<td>&lt;0.5</td>
<td>&lt;0.1</td>
<td>&lt;0.1</td>
</tr>
<tr>
<td>Butyric acid, %</td>
<td>&lt;0.5</td>
<td>0</td>
<td>0.5-1.0</td>
</tr>
<tr>
<td>Ethanol, %</td>
<td>0.2-1.0</td>
<td>0.5</td>
<td>0.5-1.0</td>
</tr>
<tr>
<td>Ammonia-N, %</td>
<td>10-15</td>
<td>&lt;12</td>
<td>8-12</td>
</tr>
</tbody>
</table>

1 Percent of dry weight

**SOURCE:** Kung, Limin and Randy Shaver. 2003. 3(13). Focus on Forage. Wisconsin Team Forage. UW Extension.
Gas fermentation: A promising diagnostic tool

Have You Kept Pace...
Fermentrics™ Interpretation and Guidelines

September 2013

Fermentrics™ is a novel laboratory method utilizing a batch-culture, rumen-fluid, gas-fermentation system combined with mathematical curve-peeling techniques allowing for the differentiation of rapid and slowly-fermenting carbohydrate pools in individual feedstuffs or TMR samples. The rate and extent of organic matter degradation, employing hundreds of data points, can be determined with Fermentrics™ by monitoring gaseous fermentation products (CO₂, methane) of microbial metabolism in addition to CO₂ produced by the buffering of microbial produced short-chained fatty acids (SCFA, primarily propionate, acetate and butyrate). This allows for a direct approach to determining carbohydrate pool (B₁, B₂, B₃) digestion rates to more accurately populate feed libraries in newer ration-balancing software. Fermentrics™ reports incorporate traditional nutritional parameters with unique analytes such as direct measurement of microbial biomass production and a microbial approach to measuring soluble protein.

SOURCE: Dairyland Laboratories, Inc.
While gas-fermentation systems are quite popular among European researchers there are only a few research labs in North America with gas-fermentation capabilities and they are not capable of processing and handling the sample volume needed in a commercial offering. The desire to provide more dynamic and diagnostic nutritional tools led to an August, 2010 joint initiative between Dairyland Laboratories, Inc. and RFS Technologies to commercialize Fermentrics™ and make this cutting-edge analysis widely available to North American livestock producers and their nutritionists.

RFS Technologies™ is a full service agricultural testing and research laboratory located Ottawa, Canada who have spent decades researching and field-testing Fermentrics™ out of the frustration of not being able to use current analytical techniques to understand and manipulate the biological potential of the rumen. This is not to diminish the value of wet chemistry or NIR analyses, but rather to point out their static nature which does not provide the dynamic or diagnostic approach needed to generate both qualitative and quantitative information on the rate and extent of digestion in a practical and inexpensive manner. Fermentrics™ is based on research conducted at Cornell University, University of Kentucky, the University of California, the Rowett Research Institute, the University of Hohenheim and the DLO Institute for Animal Science and Health.

SOURCE: Dairyland Laboratories, Inc.
Forage Testing – Keeping Pace

- Rapid tests are available using standard protocols for accuracy
- Efforts to standardize tests and protocols have been driven by research and extension
- Standardization of fiber digestibility, protein and starch tests across forage and grain products is needed

Have You Kept Pace...
Quality terms - Needed

Have You Kept Pace...
Recommended Reading

- **Forage sampling frequency**
  [http://www.uwex.edu/ces/crops/uwforage/ForageSamplingFrequency-FOF.pdf](http://www.uwex.edu/ces/crops/uwforage/ForageSamplingFrequency-FOF.pdf)

- **In vitro NDF digestibility**
  [http://www.uwex.edu/ces/crops/uwforage/30vs48-FOF.htm](http://www.uwex.edu/ces/crops/uwforage/30vs48-FOF.htm)

- **Relative forage quality**
  [http://www.uwex.edu/ces/crops/uwforage/RFQ-FOF.pdf](http://www.uwex.edu/ces/crops/uwforage/RFQ-FOF.pdf)

- **Heat damaged forages**