Factors to Account For When Balancing Rations Around Ensiled Corn (Corn Silage & High Moisture Corn)

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Observe the Obvious To Stay Out of the Ditches
Hierarchy of Ensiled Corn Feeding Considerations

◆ Recognize the obvious
  • Quality variability during feedout
  • Moisture/maturity
  • Grain particle size/distribution
  • Forage particle size/distribution
  • Duration of storage times (increased starch digestion)
  • Feed delivery and cow-side observations

◆ Employment of current laboratory analytical offerings
  • NDF digestion
  • Starch availability
  • Physical forage chop length and grain particle size

◆ Ration balancing considerations
  • Energy supplementation and sources
  • Protein supplementation opportunities
  • Assessing for total physically effective fiber (peNDF)
Silo Safety Practices Must Be Followed When Working Around and in Silos

- Many horizontal silos are built too high to be safe
- Upright silo dangers
- Potential respiratory ailments from inhaling silage odors
Know What’s Being Fed Out of the Silos
Using Thermo Imaging to Demonstrate Aerobic Instability at Silo Face

- Digital image shows loose face with loose silage on floor of silo (circled)
- IR image shows varying temperatures across the face
  - 127° temp is silo floor
  - 118° is loose silage on floor of silo
- One can conclude there are micro-fermentation environments on this face that are undergoing aerobic instability

Non-Contact Thermometer Will Get You There For ~ $50-100
Managing for Nutrient Variation: Top to Bottom of Silo Face

Table 1. Deviations between different regions (upper, middle, and lower thirds of silos higher than 12 ft; upper and lower regions of silos less than 12 ft high) of 9 haylage and 11 corn silage bunker silos (Stone et al., 2003).

<table>
<thead>
<tr>
<th></th>
<th>DM</th>
<th>CP</th>
<th>ADF</th>
<th>NDF</th>
<th>NE\textsubscript{L}</th>
<th>Lactate</th>
<th>Acetate</th>
<th>Total VFA</th>
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<tbody>
<tr>
<td>Haylage</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Smallest deviation, %</td>
<td>5.2</td>
<td>3.3</td>
<td>1.1</td>
<td>5.4</td>
<td>1.6</td>
<td>5.2</td>
<td>25</td>
<td>7</td>
</tr>
<tr>
<td>Largest deviation, %</td>
<td>44.7</td>
<td>52.1</td>
<td>20.0</td>
<td>24.8</td>
<td>20.0</td>
<td>646</td>
<td>163</td>
<td>287</td>
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<tr>
<td>Average deviation, %</td>
<td>21.0</td>
<td>17.6</td>
<td>10.7</td>
<td>14.7</td>
<td>9.9</td>
<td>112</td>
<td>72</td>
<td>69</td>
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<tr>
<td>Median deviation, %</td>
<td>19.4</td>
<td>9.5</td>
<td>9.9</td>
<td>14.4</td>
<td>9.3</td>
<td>57</td>
<td>50</td>
<td>38</td>
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<td>Com silage</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Smallest deviation, %</td>
<td>1.3</td>
<td>2.5</td>
<td>2.3</td>
<td>0.5</td>
<td>1.4</td>
<td>3.8</td>
<td>11.2</td>
<td>0.1</td>
</tr>
<tr>
<td>Largest deviation, %</td>
<td>55.0</td>
<td>29.5</td>
<td>18.3</td>
<td>18.6</td>
<td>5.6</td>
<td>48.7</td>
<td>131</td>
<td>41.3</td>
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<tr>
<td>Average deviation, %</td>
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<td>11.0</td>
<td>8.4</td>
<td>8.6</td>
<td>3.1</td>
<td>25.6</td>
<td>53.7</td>
<td>20.5</td>
</tr>
<tr>
<td>Median deviation, %</td>
<td>8.3</td>
<td>10.0</td>
<td>8.6</td>
<td>8.4</td>
<td>2.8</td>
<td>26.0</td>
<td>29.9</td>
<td>21.4</td>
</tr>
</tbody>
</table>

\textsuperscript{1}DM = Dry matter, CP = crude protein, ADF = acid detergent fiber, NDF = neutral detergent fiber, NE\textsubscript{L} = net energy for lactation, and VFA = volatile fatty acids.
Using Thermo Imaging to Demonstrate Loose Silage Not Fed Daily

Area of silage removed showed 123°F silage
### Example of %DM Variation Across the Silo Face

<table>
<thead>
<tr>
<th>Variations</th>
<th>28.9</th>
<th>30.1</th>
<th>31.3</th>
<th>32.0</th>
<th>31.8</th>
<th>33.3</th>
<th>34.1</th>
<th>31.3</th>
<th>37.8</th>
<th>34.5</th>
<th>35.4</th>
<th>35.4</th>
<th>32.8</th>
<th>36.5</th>
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</thead>
<tbody>
<tr>
<td>AVG.</td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>

- **Range = 28.9 – 37.8 (8.9)**

**Bolinger, Pioneer Hi-Bred 2010**

<table>
<thead>
<tr>
<th>Variations</th>
<th>32.8</th>
<th>33.6</th>
<th>33.9</th>
<th>34.3</th>
<th>33.9</th>
<th>33.9</th>
<th></th>
<th></th>
<th></th>
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</tr>
</thead>
<tbody>
<tr>
<td>AVG.</td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- **Range = 31.8 – 34.3 (2.5)**
Example of % Starch Variation Across the Silo Face

<table>
<thead>
<tr>
<th>AVG.</th>
<th>29.6</th>
<th>30.5</th>
<th>32.8</th>
<th>30.3</th>
<th>31.4</th>
</tr>
</thead>
<tbody>
<tr>
<td>30.7</td>
<td>28.6</td>
<td>27.0</td>
<td>31.8</td>
<td>32.9</td>
<td>30.5</td>
</tr>
<tr>
<td>29.6</td>
<td>29.6</td>
<td>31.1</td>
<td>36.7</td>
<td>36.5</td>
<td>29.1</td>
</tr>
<tr>
<td>30.6</td>
<td>37.6</td>
<td>31.9</td>
<td>25.9</td>
<td>37.4</td>
<td>37.4</td>
</tr>
<tr>
<td></td>
<td>26.8</td>
<td>31.5</td>
<td>25.7</td>
<td>28.7</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Range = 25.9 – 37.6 (10.8)

Bolinger, Pioneer Hi-Bred 2010

Range = 29.6 – 32.8 (3.2)
Example of %NDFD (24 hr)
Variation Across the Silo Face

Range = 38.1 – 51.1 (13.0)
Range = 43.0 – 47.2 (4.2)

Bolinger, Pioneer Hi-Bred 2010
How Do We Manage For Dry Matter Intake Variations?

From:

To:

Bolinger, Pioneer Hi-Bred 2010
Mix Your Feed Before You Mix It!

Bolinger, Pioneer Hi-Bred 2010
On-Site Tools to Utilize For Assessment of Corn Silage Quality

Penn State Separator

Z-Box from Miner Institute

32-oz beverage cup at silo side can tell lots about the silage
Chop Lengths and Kernel Processing Critical in Determining How Corn Silage Will Feed To Dairy Cows

An example of a very poor job of processing
Ro-Tap Lab Method Can Quantify peNDF Determinations

Test is offered by Agri-Labs in Guelph, ONT

- Quantifies % of starch in damaged vs. undamaged kernels
- Starch not as available in kernels on or above the 4.75mm screen (¼ kernel pieces and greater)
- The 4.75 mm screen is the most important sieve
- Starch more available in kernels below this screen

<table>
<thead>
<tr>
<th>Sieve (mm)</th>
<th>Interpretation</th>
</tr>
</thead>
<tbody>
<tr>
<td>19</td>
<td>coarse</td>
</tr>
<tr>
<td>13</td>
<td>coarse</td>
</tr>
<tr>
<td>9.5</td>
<td>coarse</td>
</tr>
<tr>
<td>6.7</td>
<td>coarse</td>
</tr>
<tr>
<td>4.75</td>
<td>coarse / % starch</td>
</tr>
<tr>
<td>3.35</td>
<td>medium</td>
</tr>
<tr>
<td>2.36</td>
<td>medium</td>
</tr>
<tr>
<td>1.18</td>
<td>medium</td>
</tr>
<tr>
<td>0.6</td>
<td>fine</td>
</tr>
<tr>
<td>pan</td>
<td>fine</td>
</tr>
</tbody>
</table>

Also calculates peNDF using fiber above 1.18mm screen as the pe factor (wet sieving using the Penn State Separator does not give valid peNDF values)
Sieving HMC

- Sieves #4, 8, 16, 30, and pan
- Available from Seedboro Equipment Co. 312-738-3700 for $200
- Use a fixed amount (100 - 200 g)
- Calculate proportion of grain on each screen
- Dry ground corn retained on #4 or 8 sieves may not digest well
- Finer grinds may be better utilized but amount fed, fiber feeding & feeding management must be good

Source: Mike Hutjens, University of Illinois and Mary Beth Hall, University of Florida
## Corn Grain Particle Size Guidelines

<table>
<thead>
<tr>
<th>Screen</th>
<th>#4</th>
<th>#8</th>
<th>#16</th>
<th>#30</th>
<th>Pan</th>
</tr>
</thead>
<tbody>
<tr>
<td>HM Corn (&gt;30%)</td>
<td>75</td>
<td>25</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>HM Corn (25-30%)</td>
<td>25</td>
<td>50</td>
<td>25</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>HM Corn (&lt;25%)</td>
<td>0</td>
<td>&lt;10</td>
<td>30</td>
<td>50</td>
<td>&lt;20</td>
</tr>
<tr>
<td>Dry Corn</td>
<td>0</td>
<td>&lt;10</td>
<td>30</td>
<td>50</td>
<td>&lt;20</td>
</tr>
</tbody>
</table>

The dryer the corn, the less recommended on the larger screens, reflective of reduced starch availability as protein-starch matrix becomes more complexed.

**Source:** Mike Hutjens, PhD  
2002 Four State Professional Dairy Management Seminar
## Relative Corn Index (RCI)

<table>
<thead>
<tr>
<th>Screen</th>
<th>Factor</th>
<th>Coarse Corn</th>
<th>Fine Corn</th>
</tr>
</thead>
<tbody>
<tr>
<td>#4</td>
<td>1</td>
<td>10</td>
<td>0</td>
</tr>
<tr>
<td>#8</td>
<td>2</td>
<td>30</td>
<td>10</td>
</tr>
<tr>
<td>#16</td>
<td>3</td>
<td>45</td>
<td>40</td>
</tr>
<tr>
<td>#30</td>
<td>4</td>
<td>10</td>
<td>40</td>
</tr>
<tr>
<td>Pan</td>
<td>5</td>
<td>5</td>
<td>10</td>
</tr>
<tr>
<td>RCI Score</td>
<td></td>
<td>270</td>
<td>350</td>
</tr>
</tbody>
</table>

### Score <200
- High moisture corn (>28%)
- High starch corn silage (>35%)
- High starch rations (>28%)
- Finely chopped forages

### Score >300
- Dry corn
- Low starch corn silage (<30%)
- Modest starch rations (<28%)
- Legume-based forages
- TMR with adequate particle size

Source: Mike Hutjens, PhD
2002 Four State Professional Dairy Management Seminar
Example of HMC Particle Size Data From Commercial Laboratory

Key Measurements
- mean particle size = 1254 µ
- SD = 2.74
- Moisture = 27%

Nutritionist’s HMC Goals:
- 28-30% moisture
- 750 - 800 microns +/- 50
- SD of < 2.5

<table>
<thead>
<tr>
<th>U.S. SIEVE #</th>
<th>MICRON OPENING</th>
<th>WEIGHT (GRAMS)</th>
<th>PERCENT</th>
<th>PERCENT LESS THAN</th>
</tr>
</thead>
<tbody>
<tr>
<td>8</td>
<td>2360</td>
<td>35.9</td>
<td>36.97%</td>
<td>63.03%</td>
</tr>
<tr>
<td>12</td>
<td>1700</td>
<td>16.8</td>
<td>17.30%</td>
<td>45.73%</td>
</tr>
<tr>
<td>16</td>
<td>1180</td>
<td>12.1</td>
<td>12.46%</td>
<td>33.26%</td>
</tr>
<tr>
<td>20</td>
<td>850</td>
<td>9.4</td>
<td>9.65%</td>
<td>24.61%</td>
</tr>
<tr>
<td>30</td>
<td>600</td>
<td>5.1</td>
<td>5.28%</td>
<td>19.16%</td>
</tr>
<tr>
<td>40</td>
<td>425</td>
<td>4.2</td>
<td>4.33%</td>
<td>15.04%</td>
</tr>
<tr>
<td>50</td>
<td>300</td>
<td>3.3</td>
<td>3.40%</td>
<td>11.67%</td>
</tr>
<tr>
<td>70</td>
<td>212</td>
<td>2.3</td>
<td>2.37%</td>
<td>9.68%</td>
</tr>
<tr>
<td>100</td>
<td>150</td>
<td>2.7</td>
<td>2.78%</td>
<td>4.99%</td>
</tr>
<tr>
<td>140</td>
<td>106</td>
<td>1.9</td>
<td>1.96%</td>
<td>3.53%</td>
</tr>
<tr>
<td>200</td>
<td>75</td>
<td>2.6</td>
<td>2.69%</td>
<td>0.85%</td>
</tr>
<tr>
<td>270</td>
<td>53</td>
<td>1.6</td>
<td>1.85%</td>
<td>0.00%</td>
</tr>
<tr>
<td>PAN</td>
<td>45</td>
<td>0.0</td>
<td>0.00%</td>
<td>0.00%</td>
</tr>
<tr>
<td>TOTAL</td>
<td></td>
<td>97.1</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

ANALYSIS
Mean Particle Size (DGW): 1254 microns
Standard Deviation (DGW): 2.74
1 Standard Deviation Distribution: 458 - 3414 microns
Surface Area (CM^2) / Gram: 60.2
Particles / Gram: 36924

DESC: hmc 27%
TARGET LEVEL DATA BY KANSAS STATE FOR SWINE DIETS
MANURE SCREENING

- Rumen
  - Passage of split soybeans
  - Presence of whole cottonseed
- Processing
  - Appearance whole soybeans
  - Presence of whole corn seed
  - Presence of forage particles over 1/2”
- Combination of rumen and processing
  - Appearance of starch in corn seed

Source: Mike Hutjens. Presentation at 2004 World Dairy Expo
Testing manure for starch content remains controversial

University of Pennsylvania researchers equation to estimate total tract starch digestibility

- Apparent Digestibility of Starch = 0.9872 - (0.0176 times percent fecal starch, DM basis). \( (R^2 = 0.73) \)
- Pennsylvania researchers suggest that fecal starch be under 5 percent, and that each additional one-percentage-point decline in fecal starch can support 0.67 pound of additional milk at the same dry-matter intake.

University of Illinois research from 19 herds in southwestern Illinois.

- Average fecal starch content was 6 percent, with a range of 3.9 to 9.9 percent.
- Resulted in an average starch digestibility of 84.6 using an Illinois formula: Apparent Digestibility of Starch = 93.73 - (2.61 x % fecal starch) + (0.91 x % fecal lignin). \( (R^2 = 0.73) \)

When taking a composite sample, be sure to sample five to 10 cows and send in 1 to 2 cups of manure for testing (check with your lab first).
Why Process Corn Silage and HMC?

- The primary reasons to process grains is to improve the starch availability by increasing surface area or disrupting starch granule:protein matrix.

- Processing generally improves the feeding value of grains from 5-15%.
Vitreous endosperm. Also called horneous, corneous or hard endosperm. Primary starch in flint corn. Most commercial hybrids are 55-65%. Source of dry milling grits. Tightly compacted and translucent. Laid-down and complexed with zein proteins late in the grain maturation process. Higher levels in mature, high test weight, high density kernels.

Floury endosperm. Floury starch is more “open” in structure yet opaque in appearance. At full maturity, dent corn contains about equal proportions of hard to floury starch.

Pericarp (bran): 3-6% of corn (25% of oats) but half of total kernel NDF (10%). Pericarp can remain attached to some starch and tenacity of adherence can limit bacterial access. A larger kernel may be advantageous by having less pericarp as a % of total (starch) weight.

Germ Most ash, oil and essential amino acids are in the germ. For each 1% increase in oil, expect 1.3% decrease in starch.

Hilum or abscission layer. Also called black layer. Caused by collapse and compression of several layers of cells at physiological maturity. When this appears, no more starch will be deposited in the kernel.

To Allow Starch Granule Accessibility, Damage to the **Pericarp** is Critical

**Pericarp (bran):** Half of total kernel NDF (10%). Pericarp can remain attached to some starch and tenacity of adherence can limit bacterial access. A larger kernel may be advantageous by having less NDF and less pericarp as a % of total weight.
What about Floury vs. Vitreous Endosperm

Extent of vitreousness best determined by:
- Physical dissection
- Measuring absolute density (not test weight)
- Stenvert mill grinding method

Common Terminology
- Dent vs. flint grain
- Floury vs. vitreous starch
- Soft, porous vs. hard, dense
- Light vs. heavy test weight
- Floury vs. horny endosperm
- Opaque vs. translucent
2002 work on vitreousness, per se, out of Randy Shaver's lab in Wisconsin reported that.....Ruminal starch availability showed a decline after the BL (blacklayer) stage of maturity....

2002 work on vitreousness, per se, out of Randy Shaver's lab in Wisconsin reported that.....Ruminal starch availability showed a decline after the BL (blacklayer) stage of maturity....


Note: This study was conducted with fresh kernels that had not undergone any of the effects of fermentation

Starting at the early-dent stage of maturity, the middle portion of nine ears of the U.S. hybrids was evaluated twice a week and harvested at three maturity stages; one-half milk line (HM), black layer (BL), and 21 d after BL (mature; MT). Age at harvest was defined by the number of days in the interval between the planting date and harvest date. Kernels were frozen, shelled while frozen, and dried at 60°C for 48 hours.
2005 paper out of Denmark looking at starch digestibility of a very flinty French hybrid harvested (and processed) as corn silage at 25, 35 and 40% DM.

- The ruminal starch digestion did decrease from 93 to 91%... when the fresh crop was analyzed.
- After the crop was fermented, no difference in ruminal starch digestion was detected due to maturity even in this flinty germplasm harvested as mature as 40% DM!
When fed as high moisture corn or steam flaked, the ruminal starch digestibility differences are extremely small (1-2%).

When fed as dry rolled grain, ruminal starch digestibility between hybrids did differ by 10%.

Bottom line: moving from CS to dry corn will change the amount of ruminal starch availability much more than changing hybrid genetics.

Source: F.N. Owens, Pioneer Research
Nutritionists need to recognize that well-processed corn silage and HMC has much faster rumen digestion kinetics.

Source: Dr. Bill Stone, Cornell University
Maturity of Crop Determines Starch Digestibility Endosperm Variation

WPCS Grain

Greater Than

25% Moisture

Minimal STRd difference due to endosperm type

HMC Grain

Less Than

25% Moisture

STRd difference impacted by endosperm type

Dry Grain
Moisture of Corn vs ADG and ME

MOISTURE CONTENT, %
Effect Of Time In Storage In Silo On Nutritional Value

AMAT = % Soluble Protein
A2 = % Starch

\[ y = 0.0507x + 46.765 \]
\[ R^2 = 0.9432 \]

\[ y = 0.0424x + 47.846 \]
\[ R^2 = 0.8822 \]

ESSAI ENSILAGE DE MAÏS 2001/2002 - CENTRALYS
NE Study of Corn Grain Processing Methods

Changes in ISDMD

Changes in ISDMD over time for different processing methods. The graph shows the percentage change in ISDMD (In situ dry matter digestibility) over the ensiling period (d) for different methods:

- DRC
- 24 HMC
- 28RECON
- 30 HMC
- 35RECON

The x-axis represents the ensiling period in days, ranging from 0 to 392. The y-axis shows the percentage change in ISDMD, ranging from 0 to 100%. The data points are indicated by different markers, and the lines connect them to show the trend over time.
Field use of currently available lab procedures were discussed including:

- 1) production of glucose in 7 hours with addition of amylase
- 2) DSA (direct starch assay) test
- 3) corn silage processing score
- 4) *in vitro* incubation for specific time periods with or without additional incubation with intestinal enzymes
- 5) the gas production curves with pool size estimating procedures used by Ritchie Feeds (Jay Johnston)

Points of discussion

- Grain genetics and processing factors were suggested to alter the subdivision of dietary starch within feeds into fast and slow digesting pools
- Focus was on need to develop methods to provide values for pool sizes that could be fitted into the CNCPS model to estimate extent of ruminal digestion
- Post-ruminal digestion of starch leaving the rumen, though mentioned by the panel, seemed of little concern despite the fact that starch fermented in the large intestine has limited energy value and may have adverse nutritional effects (HBS),
- Participant discussion centered on acidosis problems from too rapid ruminal starch digestion

Larson and Hoffman published work in 2008 on an easier lab method to quantify corn starch based on (zein) proteins.

Prolammin Values in Corn: Floury, opaque and well fermented high moisture corns generally have < 4 g prolamin/100 g starch while highly vitreous dry corns have > 7-10 g of prolamin/100 g starch. A numerical guide to prolamin values in corn feed grains is presented in Table 1 below.

Table 1. Corn prolamin content classifications.

<table>
<thead>
<tr>
<th>Prolamin % of Starch</th>
<th>Classification</th>
</tr>
</thead>
<tbody>
<tr>
<td>&gt;10.0</td>
<td>Extremely High</td>
</tr>
<tr>
<td>10.0</td>
<td>Very High</td>
</tr>
<tr>
<td>9.0</td>
<td>High</td>
</tr>
<tr>
<td>8.0</td>
<td>Moderate</td>
</tr>
<tr>
<td>7.0</td>
<td>Low</td>
</tr>
<tr>
<td>&lt;2.0</td>
<td>Very Low</td>
</tr>
</tbody>
</table>

Kernel Proteins (Prolamins, Zein)

- Proteins surrounding starch granules consist of prolamins, like zeins, and other proteins (albumins, globulins, glutelins).
- Prolamins are the starch encapsulating storage proteins of interest because they are proven to interfere with starch digestion.
- They derive their name from a relatively high content of the amino acid proline (and glutamine).
- Corn prolamins tend to be in higher concentrations in the vitreous (glassy) endosperm than in floury endosperm.
- Prolamins for each cereal grain have specific and historic names (wheat-gliadins, oats-avenins, barley-hordeins) and small grains have lower prolamin content than corn (zeins) or sorghum (kafirins).


Effects of changing *Prolamin as % of Starch*, on Relative Grain Quality (RGQ)
70% Starch, 9% CP, 4% Fat, 8.5% NDF, MPS – 1200 microns,
Processing Classification - Medium

<table>
<thead>
<tr>
<th>% Prolamin</th>
<th>Prolamin as % Starch</th>
<th>Relative Grain Quality (RGQ)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Dry Corn (85% DM)</td>
</tr>
<tr>
<td>10</td>
<td>14.0</td>
<td>104</td>
</tr>
<tr>
<td>8</td>
<td>11.4</td>
<td>113</td>
</tr>
<tr>
<td>6</td>
<td>8.6</td>
<td>125</td>
</tr>
<tr>
<td>4</td>
<td>5.7</td>
<td>140</td>
</tr>
<tr>
<td>2</td>
<td>2.9</td>
<td>157</td>
</tr>
<tr>
<td>0</td>
<td>0</td>
<td>177</td>
</tr>
</tbody>
</table>

*Figure 1. Graphic representation of equations used to estimate in vivo total tract starch digestibility in the UW Feed Grain Evaluation System.*

Source: http://www.uwex.edu/ces/dairynutrition/documents/WisconsinFGES.pdf
**Impact of Endosperm Storage Proteins (Prolamins, Zein) Ability to Predict Ruminant Starch Digestion**
*(Validation on Live Animals is Needed)*

- If concentration of total zeins (prolamins) in corn grain alters starch accessibility in vivo, one would expect that site and extent of starch digestion would be proportional to concentration of zeins or the zein:protein ratio.

- In an unpublished steer digestion trial, grains from isogenic hybrids that differed in content of zeins were fed.
  - reducing the concentration of zein failed to increase starch disappearance in the rumen, small intestine, large intestine, or total tract when these grains were fed as either dry rolled or steam flaked grain.
  - However, with dry rolled grain, ruminal degradation of dietary protein tended to be greater for the hybrid with reduced zeins, indicating that protein digestibility had been increased (Owens, 2009).
  - Failure for a reduction in zeins to improve starch digestion by steers fed isogenic corn hybrids in this trial makes one question the practical importance of total prolamin concentration relative to other factors (particle size, pericarp shielding, degree of disulfide linkage) that can alter accessibility of starch for digestion and the energy availability of dry rolled corn grain (Owens, 2009).

Digestion Rate Methodology Provides Means to Determine Fate of Carbohydrates in the Ruminant

- Digestion rate carbohydrate pools
  - Fast
  - Slow
- Provides inputs CNCPS and CPM
Comparison of Fast and Slow Pool Digestion Rates
(similar starch concentration both samples)

Lower $K_d$ rates and Long time (hrs) to max $K_d$

Faster $K_d$ rates and Shorter time (hrs) to max $K_d$
Consider Where Digestion Occurs In The Ruminant

- Fermentation Digestion by Microbes
- Intestinal Digestion by Animal Enzymes
- Hindgut Digestion by Microbes

**Equations:**
- $K_p$
- $K_d$
- $I_d$

**Processes:**
- Rumen by-pass
- Rumen by-pass

**Substances:**
- Starch
- Fiber
You Simply Can **Not** Feed Corn Silage With **Too** Much Starch

◆ 70 lbs wet (30%DM) CS

◆ Even at 45% starch you only feed 9.5 lbs starch/cow/day \((21 \text{ lbs DM} \times 0.45 = 9.45)\)
  - If eating 55 lbs DMI that is only 17% starch in the ration from corn silage
  - Compare to comfort level of 25-30% starch in the ration…\(55 \times 0.25 = 13.8\) lbs total starch.

Know the starch content, adjust for rates of ruminal digestion and balance around it, => simply means a less expensive ration.
Stover Considerations in Corn Silage

- NDF Contribution
- NDF Digestion
- Physically Effective NDF
Corn Ear Development Has a Dilution Effect on Relative NDF Contribution in Corn Silage

As Starch Concentration Increases, NDF Concentration Decreases

Starch deposition in grain and NDF digestion are not mutually exclusive in hybrids.

Corn silage can possess high starch concentration and high NDF digestibility by increasing corn silage in the ration, or use of non-forage fiber sources.
NDF Nutrient Availability to the Ruminant

A Look at Cell Wall Structure

⇒ Lignification reduces availability of Cellulose and Hemicellulose
Fiber Digestion of the Cell Wall

- **Lignin Concentration Gradient**
  - **Primary Wall**: Can be fairly lignified and NDFD still remains high
  - **Secondary Wall**: NDFD drops fast when thickened and lignified

- **Cell contents**: high in sugars
Can Lignin Be Used to Calculate NDFD?

◆ Impact on digestion
  • Directly: The indigestible portion of NDF
  • Indirectly: inhibits digestion of chemically associated fiber

◆ More descriptive to use lignin/NDF to calculate NDFD

\[
e_{\text{true digestible NDF}} = 0.75 \left( \text{NDF} - \text{NDICP} \right) - L \left( 1 - \frac{L}{\left( \text{NDF} - \text{NDICP} \right)^{0.667}} \right)
\]

Assumptions:
- digestibility coefficients
- chemical associations

Cell-wall digestibility as a function of lignin and cell-wall surface area
Degradable cell walls calculated by difference
Estimated and constant digestion coefficient
Lignin Content Alone Is Not Well Associated With Fiber Digestibility.

Genetic Manipulation of Cell Walls

Identification of Cell Wall Traits that can be Manipulated to Improve Forage Digestibility

Hans Jung

grass, orchardgrass, switchgrass, big bluestem, and corn) we have observed no correlation, or even positive correlations, between lignin concentration and cell-wall digestibility when the influence of maturity is removed (Halim et al. 1989, Jung and Casler 1991, Jung and Russelle 1991, Jung and Vogel 1992, Jung and Buxton 1994).

Why Measure NDFD in vitro vs. Calculating Via Lignin?

- Lignin wet chem assay difficult and its calibration with NIRS has been poor
- Lignin to NDFD equation is theoretically based
- Lignin explains about half of the in vitro NDFD variation

- Stover NDF and lignin contents & NDFD with maturity, while WP NDF and lignin contents are constant or as % grain increases

Randy Shaver, UW 2006
There is no doubt that fiber digestibility is important to energy availability and DM intakes.

- Michigan researchers, Oba and Allen (1999), reported that enhanced forage NDF digestibility significantly increased dry matter intake and milk production of dairy cows.
  - One unit increase in NDFD was associated with .37 lb increase in DMI
  - Literature review shows one unit increase of NDFD = 0.53 lb. milk

(Source: Allen, Coors, Roth. 2003. Silage Science and Technology Monograph #42)
Increased Corn Silage NDFD Results Tends to Show Increased Milk Production. Note F/E of low to high forage rations.

<table>
<thead>
<tr>
<th></th>
<th>Ration = 40% forage</th>
<th>65% forage</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>40% forage</td>
<td>65% forage</td>
</tr>
<tr>
<td>Corn silage type =</td>
<td>bmr</td>
<td>control</td>
</tr>
<tr>
<td>NDF, % ration DM</td>
<td>28.7</td>
<td>37.5</td>
</tr>
<tr>
<td>Starch, % ration DM</td>
<td>37.2</td>
<td>26.1</td>
</tr>
<tr>
<td>DM Intake, kg/d</td>
<td>24.7</td>
<td>22.9</td>
</tr>
<tr>
<td>Ration DM Dig., %</td>
<td>67.0</td>
<td>66.2</td>
</tr>
<tr>
<td>CS IV NDF Dig., % at 30 h</td>
<td>55.9</td>
<td>55.9</td>
</tr>
<tr>
<td>3.5% fat-corrected milk, kg/d</td>
<td>35.6</td>
<td>35.8</td>
</tr>
<tr>
<td>Feed Efficiency, kg Milk/kg DMI</td>
<td>1.44</td>
<td>1.56</td>
</tr>
</tbody>
</table>

Source: Dave Mertens, 2004 Discrepancies in Capturing Forage Improvements by the Cow - Oba and Allen, 2000
Comparison of Alfalfa and Corn Silage
Quality Based on Stage Of Growth

Feed Value Comparison

Vegetative | Reproductive

Alfalfa
Corn Silage
Individual Forages Vary for NDFd
2006 Dairyland Database

Forage Crop

NDF Digestibility

Alfalfa Silage
Grass Silage
Corn Silage
Definitions and Acronyms of Digestibility

◆ Digestion: measured in the laboratory by disappearance
  • Digestibility = (nutrient measured at start - nutrient residue)/100

◆ Types of digestion
  • In situ (IS) = within the place
  • In vitro (IV) = within the glass
  • In vivo = within the living

◆ Primary analyses for digestion
  • DM = dry matter
  • OM = organic matter
  • NDF = neutral detergent fiber
  • STR = starch

◆ Timepoints: 12, 24, 30, or 48 hours

◆ Grind sizes: 1 mm; or 6 mm

◆ Examples of Common acronyms
  • IVTDMD (48 hrs, 1 mm) = in vitro true dry matter digestion
  • ISTDMD (48 hrs, 1mm) = in situ true dry matter digestion
  • IVNDFd (30 hrs, 6 mm) = NDF digestion, expressed as % of NDF
  • IVDNDF (30 hrs, 6, mm) = digestion of NDF, expressed as % of DM
  • IVSTRd (12 hrs. 6 mm) = digestion of starch, expressed as % of starch
3 considerations of digestibility in the ruminant

- **Extent** = amount digested at determined timepoint
- **Rate** = % digested per hour
- **Site** = rumen or intestine

**Rumen Kinetics (K)**

- \( K_d = \) Rate of digestion/hr
- \( K_p = \) Rate of passage/hr
- \( I_d = \) Intestinal digestion
What Timepoint is Important for NDFD?

More variation does not necessarily mean less utility
(you just have to determine methods to reduce variability and/or run more samples)

24 hour NDFD
More variability, but also more biological relevancy.
Solution – run more samples

48 hour NDFD
Less variability, but also less biological relevancy

Family of NDFD curves from repeated sub-samples run from the same forage sample

24 hrs
48 hrs

Dave Mertens, USDA FRC
# Differences in Corn Silages NDFD at Various Time Points

<table>
<thead>
<tr>
<th>Samples</th>
<th>6 hr</th>
<th>12 hr</th>
<th>24 hr</th>
<th>30 hr</th>
<th>48 hr</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>7.5</td>
<td>20.5</td>
<td>44.1</td>
<td>52.2</td>
<td>56.0</td>
</tr>
<tr>
<td>2</td>
<td>5.8</td>
<td>18.9</td>
<td>41.9</td>
<td>49.0</td>
<td>55.2</td>
</tr>
<tr>
<td>3</td>
<td>5.3</td>
<td>16.0</td>
<td>37.4</td>
<td>46.0</td>
<td>51.3</td>
</tr>
<tr>
<td>4</td>
<td>7.9</td>
<td>16.5</td>
<td>37.7</td>
<td>45.7</td>
<td>52.5</td>
</tr>
<tr>
<td>5 BMR</td>
<td>12.3</td>
<td>39.5</td>
<td>59.9</td>
<td>67.5</td>
<td>71.2</td>
</tr>
<tr>
<td>6 BMR</td>
<td>7.9</td>
<td>32.8</td>
<td>52.0</td>
<td>58.4</td>
<td>64.4</td>
</tr>
<tr>
<td>7 BMR</td>
<td>8.8</td>
<td>31.1</td>
<td>52.0</td>
<td>59.3</td>
<td>65.0</td>
</tr>
</tbody>
</table>

**Average**  
7.88  25.00  46.40  54.0  59.40  

**Range**  
89 %  94 %  49 %  40 %  34 %  

Ralph Ward, CVAS 2007
What Timepoint is Important for NDFD?

Other Considerations—Know your Lab

- Sample preparation
- Open or closed in vitro vessel systems
- German research: NDFd starts becoming less relevant beyond 24 hr in vitro incubation due to biomass utilization
- 48 hr digestions are more repeatable, but review of literature (Owens 2005) shows this measure over-predicts actual NDF digestion that will occur in the rumen of the cow.
- 48 hr digestions highly correlate with ratio of lignin to NDF
How Can We Improve Silage NDFD When Ruminants Digest only 40-70% of NDF?

Conventional hybrids have minimal NDFD differences

Four options:

1. Chop finer
2. Plant low-lignin crops
3. High-chop
4. Use inoculants designed with silage bacteria that produce enzymes that speed up fiber degradation when it gets to the rumen bacteria.
NDF Quantity and Physical Form Needs to be Considered

Van Soest’s Hotel Theory: physical form of the fiber needs to be considered along with the quantity of fiber

Physically Effective NDF (peNDF)

Cell Wall Structure
- Cellulose
- Lignin
- Hemicellulose

No Structure---no peNDF

Source: Dr. Leonard Martin – Purina (Cargill) Canada
Relationships Between NDF, peNDF, and eNDF
Z-Box from Miner Institute

- Particle separation device to determine the physical effectiveness factor (pef) of a forage or TMR using an “as fed” sample on farm.
- In conjunction with the sample NDF, peNDF can be determined through the equation pef x NDF = peNDF.
- $250 cost
  - 1 Z-Box particle box separator
  - 0.51” screen for CS and TMR’s
  - 0.58” screen for HCS
Particle Separation Determination

- Assesses particle lengths
- Tools available: Penn State System
  - Sieveswww3Nasco.com
  - Scale: Wal-Mart
- Where to use
  - TMR
  - Silo site at time of filling
  - Refusals
- What this tells
  - Over-mixing of TMR?
  - Assesses harvest processing efficiency?
  - Sorting?

Screen sizes
- 0.75 in
- 0.31 in
- 0.05 in
## Effective Fiber Availability From Several Forage Sources

<table>
<thead>
<tr>
<th>Feedstuff</th>
<th>NDF, %DM</th>
<th>% EfNDF</th>
<th>Absolute Ef NDF/lb DM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Straw</td>
<td>65</td>
<td>100</td>
<td>.65</td>
</tr>
<tr>
<td>CS 40% G:S</td>
<td>45</td>
<td>75</td>
<td>.34</td>
</tr>
<tr>
<td>CS 50% G:S (long chopped length)</td>
<td>38</td>
<td>75</td>
<td>.29</td>
</tr>
<tr>
<td>Alfalfa Hay 180 RFV</td>
<td>38</td>
<td>90</td>
<td>.32</td>
</tr>
<tr>
<td>Alfalfa Silage 180 RFV</td>
<td>38</td>
<td>82</td>
<td>.31</td>
</tr>
<tr>
<td>Wheat Silage</td>
<td>56</td>
<td>82</td>
<td>.46</td>
</tr>
</tbody>
</table>
Miner Institute evaluated the relationship between forage fiber digestibility and its fragility, or how easily the forage is broken down during chewing.

Nutritionists know that some forage fiber breaks down more quickly than others during chewing (such as straw versus high quality grass hay or corn silage).

Miner research involves methods to incorporate a measure of fragility into ration formulation.

All NDF is not the same!
Estimating Physically Effective NDF (peNDF) From Particle Size Measurements

<table>
<thead>
<tr>
<th>Feed</th>
<th>pef% X</th>
<th>NDF</th>
<th>peNDF</th>
</tr>
</thead>
<tbody>
<tr>
<td>(feed retained on 1.18 mm sieve)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Grass hay, long</td>
<td>.98</td>
<td>65</td>
<td>63.7</td>
</tr>
<tr>
<td>Alfalfa silage, course</td>
<td>.82</td>
<td>40</td>
<td>32.8</td>
</tr>
<tr>
<td>Corn silage unprocessed</td>
<td>.85</td>
<td>40</td>
<td>34</td>
</tr>
<tr>
<td>(3/8” TLC)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Corn silage processed</td>
<td>.70</td>
<td>40</td>
<td>28</td>
</tr>
<tr>
<td>(3/8” TLC)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Corn silage processed</td>
<td>.85</td>
<td>40</td>
<td>34</td>
</tr>
<tr>
<td>(3/4” TLC)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
**Physical Effective NDF (peNDF) Requirements of Dairy Cattle**

- **Minimum fiber rations using peNDF**
  - Between 19-23% of ration DM

<table>
<thead>
<tr>
<th>Forage</th>
<th>lbs. DM Fed</th>
<th>peNDF</th>
<th>lbs peNDF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wheat Straw</td>
<td>2</td>
<td>60</td>
<td>1.2</td>
</tr>
<tr>
<td>Alfalfa Silage</td>
<td>13</td>
<td>32.8</td>
<td>4.3</td>
</tr>
<tr>
<td>Corn Silage, Proc</td>
<td>13</td>
<td>34</td>
<td>4.4</td>
</tr>
<tr>
<td>Total from Forages</td>
<td></td>
<td></td>
<td>9.9</td>
</tr>
<tr>
<td>Total Ration</td>
<td>50</td>
<td>19-23</td>
<td></td>
</tr>
</tbody>
</table>

**peNDF, % DM** 19.8
Straw works even better than the corn stalk
(because it is unfermented, dry, hollow and floats better in the rumen)

- If you are new to feeding high-chop silage, and are already feeding high-forage quality to begin with, watch out for ration scratch problems (low pe-NDF) that could lead to acidosis issues.
- The high-chop CS provides a net loss of 27 minutes of chewing time, plus a net increase of 0.3 lbs of starch.
- Adding 1 lb of straw to the high-chop CS ration increased the total minutes of chewing time by 79-minutes above the conventional CS.

Ro-Tap Lab Method Can Quantify peNDF Determinations

Test is offered by Dairyland, Dairy-1, and Cumberland Valley

- Quantifies % DM retained on 1.18 mm screens and above in determining “pef” value
- Quantifies % of starch retained on 4.75 mm screens and above
- Provides particle separation information

<table>
<thead>
<tr>
<th>Sieve (mm)</th>
<th>Interpretation</th>
</tr>
</thead>
<tbody>
<tr>
<td>19</td>
<td>coarse</td>
</tr>
<tr>
<td>13</td>
<td>coarse</td>
</tr>
<tr>
<td>9.5</td>
<td>coarse</td>
</tr>
<tr>
<td>6.7</td>
<td>coarse</td>
</tr>
<tr>
<td>4.75</td>
<td>coarse / % starch</td>
</tr>
<tr>
<td>3.35</td>
<td>medium</td>
</tr>
<tr>
<td>2.36</td>
<td>medium</td>
</tr>
<tr>
<td>1.18</td>
<td>medium</td>
</tr>
<tr>
<td>0.6</td>
<td>fine</td>
</tr>
<tr>
<td>pan</td>
<td>fine</td>
</tr>
</tbody>
</table>
Opportunities For Increased Dairy Production and Efficiencies By Detailed Characterization of Corn Silage and HMC

◆ Opportunities
  • Increased utilization of cell wall carbohydrates
  • Maximizing peNDF from corn silage
  • Understanding starch availability to the ruminant

◆ Results
  • Feeding efficiency increases with lower supplemental energy sources in ration
  • Often supplemental protein can be lowered in ration
    – Taking advantage of nitrogen recycling
      ◆ Lower soluble protein in ration
    – Due to increased rumen microbial protein production
      ◆ Lower need for supplemental by-pass protein
  • Improved rumen health and overall cow health
Summary of Ensiled Corn Feeding Considerations

ён Take advantage of the obvious!
  - Minimize nutritional variability during silo feedout
  - Understand impact of moisture/maturity on feed value
  - Understand impact of grain particle size/distribution
  - Determines forage particle size and contribution to the ration
  - Realize that silo storage times increase starch digestion (and perhaps NDFD)
  - Evaluate feed delivery and make cow-side observations

ён Employment of current laboratory analytical offerings
  - NDF digestion
  - Starch availability
  - Particle size and kernel processing

ён Ration balancing considerations
  - Energy supplementation and sources
  - Protein supplementation opportunities
  - Assessing for total peNDF

ён You have an opportunity to increase feeding efficiencies
Corn Silage Feeding Pointers

**Starch**
- High levels of starch can work if you understand how the starch digestibility changes over time in (fermented) storage and attention is paid to ration peNDF and TMR sorting is minimized.
- It’s impossible to feed too much starch from corn silage, even when feeding at high inclusion rates.
- High starch CS reduces the need to purchase off-farm starch; or conversely, allows you to sell more grain off-farm.

**Fiber**
- NDFD of CS is almost always higher than the NDFD of either grass or legume.
- NDFD and starch deposition are mutually exclusive, you can have both in CS.
- peNDF of CS will be impacted by dilution from grain deposition in the crop.
The End!

Questions?