Nonfiber Carbohydrates In Forages

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Carbohydrates provide the main energy source to support high production.

However, CHO do not all function the same way in rations, or support similar performance.

Which can affect profitability.

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Non- NDF Carbohydrates (circa 1860)

\[ \text{NFE} = 100 - \text{CP} - \text{CF} - \text{EE} - \text{Ash} \]

\[ \text{NFC} = 100 - \text{CP} - (\text{NDF} - \text{NDFCP}) - \text{EE} - \text{Ash} \]

- Very digestible (98%?)
- Error pool
- Chemically and nutritionally diverse
Plant Cell Structure

Cell contents
- Organic acids
- Mono- & Oligosaccharides
- Starch
- Fructans
- Middle lamella
- Pectic substances
  - -glucans

Cell wall
- Hemicellulose
- Cellulose
- Lignin

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All NFC are not created equal.
Feed Carbohydrate → Rumen → Microbes → Escape Feed Carbohydrate → VFA

Rumen → CO₂ & CH₄ → Liver

Rumen → Tissues

Rumen → Hindgut

Absorbed Sugars & Microbial Protein
Feed Carbohydrate

Rumen

Microbes

Escape Feed Carbohydrate

CO₂ & CH₄

VFA

Tissues

Liver

Glucose

Hindgut

Manure

Absorbed Sugars & Microbial Protein
NFC Digestion Characteristics

- Organic Acids
- Sugars
- Starches
- Fructans
- Pectic Substances
- β-Glucans

- Digested by Mammalian Enzymes
- Support Microbial Growth
- Potentially Ferment to Lactic Acid
- Decreased Fermentation at Low pH

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Hall and Herejk, 2001

Maximum Microbial CP Yield

<table>
<thead>
<tr>
<th>% of Starch</th>
<th>47%</th>
<th>86%</th>
<th>88%</th>
<th>100%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Microbial CP per gram of Organic Matter</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NDF</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sucrose</td>
<td>40</td>
<td>70</td>
<td>80</td>
<td>90</td>
</tr>
<tr>
<td>Pectin</td>
<td>50</td>
<td>80</td>
<td>90</td>
<td></td>
</tr>
<tr>
<td>Starch</td>
<td>60</td>
<td>90</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
NFC Types & Sources

**Organic Acids**
- Silages
- Whey
- Steep liquor

**Sugars**
- Molasses
- Bakery waste
- Fresh forages/hays
- Beet & citrus pulps
- Almond hulls

**Starch**
- Grain silages
- Corn, sorghum
- Small grains
- Bakery waste
- Wheat midds

**Soluble Fiber**
- Legume forages
- Beet & citrus pulps
- Soybean meal

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Don’t worry. She’ll get around to why this matters.

So?
### Starch vs. Soluble Fiber + Sugar

<table>
<thead>
<tr>
<th></th>
<th>1</th>
<th>2</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Corn vs Beet Pulp</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>DM Intake, lb</td>
<td>+2.6*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Milk, lb</td>
<td>+0.7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fat, %</td>
<td>-0.18</td>
<td>-0.05</td>
<td>-0.11</td>
</tr>
<tr>
<td>Fat, lb</td>
<td>-0.07</td>
<td>+0.04</td>
<td>+0.02</td>
</tr>
<tr>
<td>Protein, %</td>
<td>+0.09*</td>
<td>+0.07*</td>
<td>+0.12*</td>
</tr>
<tr>
<td>Protein, lb</td>
<td>+0.11*</td>
<td>+0.08†</td>
<td>+0.18†</td>
</tr>
</tbody>
</table>

| **Corn vs Citrus Pulp** |    |    |    |
| DM Intake, lb  |    | +1.2* |    |
| Milk, lb       |    | +2.0 |    |
| Fat, %         |    | -0.05 |    |
| Fat, lb        |    | +0.04 |    |
| Protein, %     |    | +0.07* |    |
| Protein, lb    |    | +0.08† |    |

| **Hominy vs Citrus Pulp** |    |    |    |
| DM Intake, lb  |    |    | +1.1 |
| Milk, lb       |    |    | +3.3 |
| Fat, %         |    |    | -0.11 |
| Fat, lb        |    |    | +0.02 |
| Protein, %     |    |    | +0.12* |
| Protein, lb    |    |    | +0.18† |

* $P<0.05$, † $P<0.15$

Mansfield et al., 1994; Solomon et al., 2000; Leiva et al., 2000
Obviously, we should feed more starch.
Average Milk Loss: 744 lb/cow/episode

-220 lb milk

Averhoff and Hall, 2000
Diarrhea
Foamy manure with ground grain
Mucin casts
Net Energy and TDN are not fixed values. They change with changing rations. They decrease in unbalanced rations & when digestive processes are disturbed.

Moe, 1976
<table>
<thead>
<tr>
<th>RDP % of BW</th>
<th>Ctrl</th>
<th>Starch</th>
<th>Glc</th>
<th>Fru</th>
<th>Suc</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.031</td>
<td>60.0</td>
<td>52.5</td>
<td>45.1</td>
<td>52.0</td>
<td>41.9</td>
</tr>
<tr>
<td>0.122</td>
<td>59.3</td>
<td>61.2</td>
<td>68.1</td>
<td>71.3</td>
<td>62.3</td>
</tr>
</tbody>
</table>

At the lower level of RDP, no difference among supplements.

At greater RDP, starch differed from sugar ($P=0.05$) and mono- differed from disaccharides ($P=0.03$).

Heldt et al., 1999
## Carbohydrates: Sugar v. Starch

<table>
<thead>
<tr>
<th>Sugar:Starch (% Diet DM)</th>
<th>0:7.5</th>
<th>2.5:5.0</th>
<th>5.0:2.5</th>
<th>7.5:0</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>DM intake</strong></td>
<td>54.0</td>
<td>56.4</td>
<td>57.3</td>
<td>57.3</td>
</tr>
<tr>
<td><strong>Milk, lb</strong></td>
<td>85.8</td>
<td>89.1</td>
<td>88.2</td>
<td>86.9</td>
</tr>
<tr>
<td><strong>Fat, lb</strong></td>
<td>3.24</td>
<td>3.37</td>
<td>3.64</td>
<td>3.57</td>
</tr>
<tr>
<td><strong>Protein, lb</strong></td>
<td>2.73</td>
<td>2.82</td>
<td>2.84</td>
<td>2.82</td>
</tr>
<tr>
<td><strong>Rumen pH</strong></td>
<td>6.19</td>
<td>6.16</td>
<td>6.19</td>
<td>6.21</td>
</tr>
<tr>
<td><strong>Milk/DM</strong></td>
<td>1.60</td>
<td>1.58</td>
<td>1.54</td>
<td>1.52</td>
</tr>
<tr>
<td><strong>FPCM/DM</strong></td>
<td>1.64</td>
<td>1.63</td>
<td>1.66</td>
<td>1.64</td>
</tr>
<tr>
<td><strong>MN/IN</strong></td>
<td>0.312</td>
<td>0.291</td>
<td>0.291</td>
<td>0.295</td>
</tr>
</tbody>
</table>

L $P<=$0.05, L $P < 0.10

Broderick et al., 2002
Formulating Rations: NFC and Forage

- What balance among NFC and fiber?

- Collected rations
  - Healthy, productive cows
  - Feed analyses
  - Cows ration ~ paper ration
  - Estimated NFC fractions
NFC vs. Forage (% of ration DM)

Forage% of Diet DM

NFC% of Diet DM

Sugars
Starch
NDSF

Hall and Van Horn, 2001

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<table>
<thead>
<tr>
<th>Min. Forage NDF</th>
<th>Min. Dietary NDF</th>
<th>Max Dietary NFC</th>
</tr>
</thead>
<tbody>
<tr>
<td>19</td>
<td>25</td>
<td>44</td>
</tr>
<tr>
<td>18</td>
<td>27</td>
<td>42</td>
</tr>
<tr>
<td>17</td>
<td>29</td>
<td>40</td>
</tr>
<tr>
<td><strong>16</strong></td>
<td><strong>31</strong></td>
<td><strong>38</strong></td>
</tr>
<tr>
<td>15</td>
<td>33</td>
<td>36</td>
</tr>
</tbody>
</table>

- Slug feeding
- Empty bunks
- Cows sorting
- Heat stress

**Think**

“Risk Management”
Where do my forages fit?
Forage NFC Composition

% of Dry Matter

- Corn silage
- Alfalfa
- Timothy

- Sugar
- Starch
- Soluble Fiber

Hall, 2000
Alfalfa Leaves: NDF & Soluble Fiber

Hall et al., 1997
Alfalfa Stems: NDF & Soluble Fiber

% of Dry Matter

May 8 May 15 May 22 May 29 June 5 June 12

Hall et al., 1997
Alfalfa Plant: NDF & Soluble Fiber

% of Dry Matter

May 8  May 15  May 22  May 29  June 5  June 12

% Leaf 72  58  48  42  36  34

Hall et al., 1997

Leaf loss
Maturity
Sugars?
Corn Silage: Starch Content (% of DM)

Mean = 27.698  N = 5702

Ward, 2003
Supplement Composition

% of Dry Matter

- Corn grain
- Molasses
- Soybean meal
- Whole ctsd
- Beet pulp
- Citrus pulp

- Sugar
- Starch
- Soluble Fiber

Hall, 2000
Eaten Does Not Mean Digested

Poorly chopped/processed corn silage

Coarse corn meal

Henry, 1911
Carbohydrates and Problems

- NFC: Too much / wrong kind
- Feeding grain in large meals
- Forage: grain ratio
- Cows sorting feed

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Things To Consider

- NFC & effective NDF need to be looked at together.
- Forages will vary in NFC & effective NDF.
- Supplements must complement the forage.
- Feed for healthy, productive cows.
- We have more to learn.

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In the same way that cars need both fuel and oil to run well, cows need both NFC and fiber.
Effective Fiber

Alfalfa

Grass

Corn/Sorghum

Cottonseed hulls
Starch

Rate of digestion affected by:

- Particle size
- Plant source
- Moisture content
- Ensiling
- Steam & heat treatment

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You can’t push a cow to produce.....

....But you can get the obstacles out of her way so she can.
### Carbohydrates: Sugar v. Starch

48 cows (12 blocks of 4 cows) + 4 cannulated cows

<table>
<thead>
<tr>
<th>Ingredient</th>
<th>Percentage</th>
<th>CP</th>
<th>NDF</th>
<th>NFC</th>
<th>Fat</th>
<th>Starch</th>
<th>Sugar</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alfalfa Silage</td>
<td>40.0%</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Corn Silage</td>
<td>20.0%</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HMSC</td>
<td>20.5%</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SBM</td>
<td>9.0%</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Roasted soy</td>
<td>3.0%</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fat</td>
<td>2.0%</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Minerals</td>
<td>1.0%</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sugar</td>
<td>0 - 7.5%</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Starch</td>
<td>7.5 - 0%</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

CP 16.8%
NDF 29.6%
NFC 42.8%
Starch 28.2 - 21.5%
Sugar 2.7 - 10.0%

Broderick et al., 2002
### Digestive Upset Results – Average

<table>
<thead>
<tr>
<th></th>
<th>Avg.</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Treatment Cost:</td>
<td>$5.60</td>
<td>0 – 74.22</td>
</tr>
<tr>
<td>Lost Milk Revenue:</td>
<td>$115.37</td>
<td>6.23 – 499.92</td>
</tr>
<tr>
<td>Cull Value Loss:</td>
<td>$39.56</td>
<td>0 – 672.39</td>
</tr>
<tr>
<td>Early Cull / Dry Off:</td>
<td>$48.28</td>
<td>0 – 1900.97</td>
</tr>
<tr>
<td><strong>Total Cost:</strong></td>
<td>$208.81</td>
<td>6.21 – 2144.45</td>
</tr>
</tbody>
</table>

164 cows. Avg. milk loss: 744 lb

Averhoff and Hall, 2000
# Non-NDF Carbohydrates

<table>
<thead>
<tr>
<th>Ferm. Rates</th>
<th>VFA</th>
<th>Organic Acids</th>
<th>NDSC Analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td>30+%/h</td>
<td>Propionic Butyric</td>
<td>Mono- &amp; Oligosacc.</td>
<td>Organic Acids</td>
</tr>
<tr>
<td>4 - 30%/h</td>
<td>Propionic</td>
<td>Starches</td>
<td>Sugars</td>
</tr>
<tr>
<td>20 - 40%/h*</td>
<td>Acetic</td>
<td>Fructans</td>
<td>Starch</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Pectic Substances</td>
<td>ND-Soluble Fiber</td>
</tr>
<tr>
<td></td>
<td></td>
<td>β-Glucans</td>
<td></td>
</tr>
</tbody>
</table>

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