Non-fiber carbohydrates: What sets the right quantity and quality for rations?
To do anything well (and repeatably), we need to understand what we are dealing with.
<table>
<thead>
<tr>
<th>Min. Forage NDF</th>
<th>Min. Dietary NDF</th>
<th>Max Dietary NFC</th>
<th>Risk Management</th>
</tr>
</thead>
<tbody>
<tr>
<td>19</td>
<td>25</td>
<td>44</td>
<td>+/− Reserves</td>
</tr>
<tr>
<td>18</td>
<td>27</td>
<td>42</td>
<td>N utilization</td>
</tr>
<tr>
<td>17</td>
<td>29</td>
<td>40</td>
<td>Slug feeding</td>
</tr>
<tr>
<td>16</td>
<td>31</td>
<td>38</td>
<td>Empty bunks</td>
</tr>
<tr>
<td>15</td>
<td>33</td>
<td>36</td>
<td>Cows sorting</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Heat stress</td>
</tr>
</tbody>
</table>

Think: Energy Supply & “Risk Management”
NFC Recommendations (DM basis)

- Sugars: 5 - 7%
- Starch: 22 - 27%
- Soluble Fiber: 7 - 9%

- Use analyses, don’t just supplement.
- The recommended amount will also depend on how it was measured. ESC, WSC, ……
NFC Recommendations (DM basis)

More of a balancing act for a net result:
Quantity: Sugars, Starch

What factors alter desirable NFC levels?

R2 = 0.576

Hall and Van Horn, 2001
1. Starch: Rates Subject to Change?

Rates of Total Starch Fermentation, %/h

- Ruminal fermentation rates were increased at higher dietary starch levels.
- Change greater for rapid than slow rate.
- Starch enzyme activity ~68% on low starch diet?
- Blend starch feeds to take advantage & be safe.

Oba and Allen, 2003

Starch $P<0.001$, Corn $P<0.001$, Starch x Corn $P<0.01$
More rapidly fermented substrate should require more rapidly degraded nitrogen source. Does type matter? NH$_3$ available from recycling & protein degradation.

**NH$_3$-N% of Bacterial N**

- Glucose: 38.3
- Starch: 60.1

Sugar utilizers have a preference for amino acids / peptides?

3a. NFC x Protein Changes pH & VFA?

**Rumen pH:**
- **C, P**
- **High RANSC:**
  - High RDP: 6.29
  - Low RDP: 6.40
- **Low RANSC:**
  - High RDP: 6.26
  - Low RDP: 6.37

**VFA, millimolar:**
- **P**
- **High RANSC:**
  - High RDP: 148
  - Low RDP: 136
- **Low RANSC:**
  - High RDP: 144
  - Low RDP: 139

Aldrich et al., 1993, J Dairy Sci 76:1091-1105
Matter is neither created or destroyed, even in cows.

Did the microbes make other products because of protein:CHO?

What caused the change?

Good or bad?
3b. NFC and Protein

NFC: $P < 0.01$
SED = 3.4

Suc+RDP  Suc-RDP  Sta+RDP  Sta-RDP
- DM%  14.6  14.4  14.8  15.2
- DMI, kg  22.7  23.4  23.6  23.7
- Rumen Liquid, kg  80.6  77.9  74.4  70.0

min/d

Suc+RDP  Suc-RDP  Sta+RDP  Sta-RDP
- Rumination  N.S.  SED = 49
- Eating  CxP: $P = 0.02$  SED = 8
- Standing  CxP: $P = 0.04$  SED = 50

Hall, 2009

Taylor et al., 1991 JDS
### 3c. 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>DM intake, lb</td>
<td>54.0</td>
<td>56.4</td>
<td>57.3</td>
<td>57.3</td>
</tr>
<tr>
<td>Milk, lb</td>
<td>85.8</td>
<td>89.1</td>
<td>88.2</td>
<td>86.9</td>
</tr>
<tr>
<td>Fat, lb</td>
<td>3.24</td>
<td>3.37</td>
<td>3.64</td>
<td>3.57</td>
</tr>
<tr>
<td>Protein, lb</td>
<td>2.73</td>
<td>2.82</td>
<td>2.84</td>
<td>2.82</td>
</tr>
<tr>
<td>Rumen pH</td>
<td>6.19</td>
<td>6.16</td>
<td>6.19</td>
<td>6.21</td>
</tr>
</tbody>
</table>

**Corn or Molas.**

<table>
<thead>
<tr>
<th></th>
<th>+RDP</th>
<th>-RDP</th>
<th>+RDP</th>
<th>-RDP</th>
</tr>
</thead>
<tbody>
<tr>
<td>DM intake, lb</td>
<td>55.0</td>
<td>55.4</td>
<td>55.4</td>
<td>54.1</td>
</tr>
<tr>
<td>Milk, lb&lt;sub&gt;CxP&lt;/sub&gt;</td>
<td>90.2</td>
<td>86.0</td>
<td>88.2</td>
<td>90.0</td>
</tr>
<tr>
<td>Fat, lb&lt;sub&gt;CxP&lt;/sub&gt;</td>
<td>3.01</td>
<td>2.86</td>
<td>3.01</td>
<td>3.08</td>
</tr>
<tr>
<td>Protein, lb&lt;sub&gt;C&lt;/sub&gt;</td>
<td>2.51</td>
<td>2.33</td>
<td>2.33</td>
<td>2.29</td>
</tr>
<tr>
<td>Rumen pH</td>
<td>5.98</td>
<td>5.99</td>
<td>5.76</td>
<td>5.97</td>
</tr>
</tbody>
</table>

\( P = < 0.05, \quad P < 0.10 \)

Broderick et al., 2002; Hall et al. submitted
4. Ruminal Sucrose + Starch

Sugars & Fructans

\( \alpha \)-glucan

Starch

Fermented

Fermented

Undigested
4. Rumen Protozoa & Carbohydrates

Protozoa consume microbes and feed particles; contribute to ruminal recycling. By consuming starch granules, they may reduce the potential for ruminal acidosis. Ruminants with protozoa are less efficient than defaunated animals. Protozoa & bacteria can make glycogen.

Depending on the NFC, how do microbes vary what products they produce that the cow can use as nutrients?

Hall, unpub.
5. B-Vitamin Apparent Synthesis

Forage:NFC
35:30, 35:40, 60:30, 60:40
50% corn silage, 33% alfalfa hay, 17% grass hay
2:1 beet pulp:soyhulls or corn:barley
CP% ~16.5
NDF% 35-47%
Starch% 5-21
Sugar% 7-8

Schwab et al., J. Dairy Sci. 89:174–187
Nutrient Supply

- Intake
- Digestion → Which products?
- Passage → Digestion where?
- Interactions NFC source and....
  - NDF form & amount
  - RDP, RUP
  - pH
  - ......
NFC is important, but, to be honest, nutrient supply is likely to change as affected by me, the rest of the ration, environment, and so on.

You still need to learn how the pieces fit together.
Carbohydrate Formulation

- Carbohydrates are not created equal
- We need to explore interactions:
  - Other dietary components
  - Physical, chemical, & microbial
  - Passage effects
- Feed vs CHO effects
- We have more to learn
4. B-Vitamin Apparent Synthesis

**Forage:** NFC
35:30, 35:40, 60:30, 60:40
50% corn silage, 33% alfalfa hay, 17% grass hay
2:1 beet pulp:soy hulls or corn:barley
CP% ~16.5
NDF% 35-47%
Starch% 5-21
Sugar% 7-8

**mg/day**

[Graph showing niacin content across different formulas with NFC: <0.01 mg/day]

4a. Induction of Acute Ruminal Acidosis

Randhawa et al., 1982

- Exfoliation and ulceration with wheat but not molasses
- Liquid vs. solid passage?
- Sugar to glycogen?

Randhawa et al., 1982
2a. NFC x RDP Changes Fiber Digestion

NDF digested %

NFC at 0.3% of BW

pH, competition, bacteriocins, cross-feeding...

Heldt et al., 1999
High N or Low N pastures supplemented with a glucose monohydrate + corn flour drench (4x daily feeding of each).

<table>
<thead>
<tr>
<th>Forage Composition</th>
<th>High N</th>
<th>Low N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dry matter%</td>
<td>15.7</td>
<td>17.6</td>
</tr>
<tr>
<td>Organic matter%</td>
<td>90.4</td>
<td>90.8</td>
</tr>
<tr>
<td>Crude protein%</td>
<td>17.6</td>
<td>13.2</td>
</tr>
<tr>
<td>NDF%</td>
<td>46.0</td>
<td>45.7</td>
</tr>
<tr>
<td>Water-soluble CHO%</td>
<td>22.0</td>
<td>27.1</td>
</tr>
</tbody>
</table>

8 cows, 4x4 Latin square, 14 d periods

Carruthers and Neil, 1997
3a. NFC x Protein Changes VFA?

<table>
<thead>
<tr>
<th></th>
<th>High N</th>
<th>Low N</th>
</tr>
</thead>
<tbody>
<tr>
<td>+NFC</td>
<td></td>
<td></td>
</tr>
<tr>
<td>-NFC</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Pasture DMI, lb

- N = Nitrogen, C = NFC, X = Interaction

NH₃, mmol/L

Total VFA, mmol/L

N = Nitrogen, C = NFC, X = Interaction  \( P = \leq 0.05 \)

Carruthers and Neil, 1997
3c. Sucrose Amount Changes Yield?

- Substrates: Isolated bermudagrass NDF & Sucrose
- Two 24 h in vitro fermentations \( \text{(Goering & Van Soest, 1970)} \)
- Assessed carbon in products (microbes calc from N, VFA, calc gas, glycogen) and yield of product / sucrose fermented

Graph showing ratios to sucrose of added N & amino acids in medium and microbes, etc. in inoculum also changed.

Hall and Weimer, 2008
3c. Sucrose Amount Changes Yield?

**Total Product C, mg**

- **Suc65**: 32.8
- **Suc130**: 51.6
- **Suc195**: 63.5

**SED = 3.8**  
**P = 0.02**

Hall and Weimer, 2008
3c. Sucrose Amount Changes Yield?

Total Product C, mg

Product/Sucrose

SED = 0.05, $P = 0.02$

SED = 3.8, $P = 0.02$

Suc65: 32.8
Suc130: 51.6
Suc195: 63.5

Hall and Weimer, 2008
3c. Yield of C: Products/Sucrose

- **Microbial CP**
  - Suc65: 0.12
  - Suc130: 0.04
  - Suc195: 0.93

- **Organic acids**
  - Suc65: 0.04
  - Suc130: 0.93
  - Suc195: 0.16

- **Glycogen**
  - Suc65: 0.020
  - Suc130: 0.068
  - Suc195: 0.047

- **Gas**
  - Suc65: 0.038
  - Suc130: 0.038
  - Suc195: 0.038
2. NFC x RDP Changes Fiber Digestion

NDF digested %, 30 h in situ, sorghum silage

<table>
<thead>
<tr>
<th>Feed</th>
<th>NFC</th>
<th>RDP</th>
<th>CxP</th>
<th>SED</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gr. corn</td>
<td>&lt;0.01</td>
<td>0.07</td>
<td>&lt;0.01</td>
<td>0.02</td>
</tr>
<tr>
<td>Citrus Pulp</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mol.+Sucrose</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Carbohydrate or feed effect?

Hall et al., submitted