Maximizing Rumen Health and Efficiency

Mary Beth de Ondarza, Ph.D.
Paradox Nutrition, LLC
West Chazy, New York, U.S.A.
The Big Picture...

The Basics:

Cow Comfort  Heifers  Fresh Cows

Making the Most Of the Rumen:

Intake

Fiber Digestibility

Synchrony

Rumen Health

Amino Acids, Milk, & Milk Protein
Do You See Inconsistent Manure?

It's Probably Sub-Clinical Rumen Acidosis...
Here’s A Close-Up.. Check out the Bubbles and Pastiness

Photo courtesy of M.B. Hall
Lack of Fiber, Less Rumination, and Faster Rates of Passage

- Fiber and Grain in the Manure

More Intestinal Fermentation of Feed

- Organic acids damage intestinal wall and mucous is secreted for protection
- Gases can’t be belched out and instead end up in the manure
Sub-clinical Rumen Acidosis

- Inhibits the Growth of Rumen Bacteria, especially the Fiber Digesters
- Reduces Rate of Fiber Digestion
- Reduces Rumen Microbial Protein

Hourly Fluctuations in Rumen pH

pH < 6.0
What’s Going On in the Rumen?

A Rumen Balancing Act Goes On Each Minute of the Day
1. Management Strategies to Avoid Subclinical Acidosis

Optimizing Rumen Efficiency
Hourly Rumen pH of Cows Fed Grain 2x/day or 12x/day

French & Kennelly, 1985
Avoid Slug Feeding

- High Producing Cows Eat 9-14 Meals/Day
- Watch......
  - Number of Feedings & Push-Up’s / Day
  - Bunk Space (at least 18” (46 cm)/cow)
  - Competition Among Cows
  - Floor Surface / Footing for Cows
- Time For Eating, Drinking & Ruminating
## Daily Time Budget (Grant, 2003)

<table>
<thead>
<tr>
<th>Activity</th>
<th>Time Needed / Day</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eating</td>
<td>3-5 hours</td>
</tr>
<tr>
<td>Ruminating</td>
<td>7-10 hours</td>
</tr>
<tr>
<td>Drinking</td>
<td>30 minutes</td>
</tr>
<tr>
<td>Milking Time in Parlor</td>
<td>2-3 hours</td>
</tr>
<tr>
<td>Lying / Resting</td>
<td>10-12 hours</td>
</tr>
</tbody>
</table>
Resting & Rumination Economics

- 30% versus 0% Overcrowded
  → 25% Less Rumination on the Same TMR

- Two pounds (0.9 kg) more milk per day for each extra hour of resting due to better health and blood flow to the udder

- One Farm:
  - 20% → 13% of day in parlor
  - 36% → 49% of day resting
  - 6 – 7 lbs (2.7-3.2 kg) more milk / cow / day

Grant, 2003
Have You Ever Seen Cows Sort Through Their TMR?

Look For The Holes
When Cows Sort, You No Longer Have A TMR

- Cows eat mostly grain or mostly forage when they get to the bunk --- not a good mix of both at one time.
- Generally, they are sorting to get to the grain.
- They may eat more forage when that’s all that’s left in the bunk or their rumens start feeling acidotic.
- May decrease number of meals/day.
Watch TMR Dry Matter

The Books Will Tell You:

- 45-55% DM is fine
- Wet silage with Nasty Acids is Not Consumed As Well As Drier Silage

On-Farm Research Says:

- Add Water to get Ration DM to 43-44%
- Regardless of Ration DM, Water May Help to Bind Grain Particles to Forage Particles
Feeding Behavior

High-Producing Cows Eat 9-14 Meals Per Day

2 X vs. 1 x TMR Feeding:
→ 10 min. more feeding/day
→ less TMR sorting

99 vs. 51 cm Feedbunk Space:
→ 57% Fewer Hostile Interactions
→ 10% More Eating Time/Day

Submissive Cows Most Affected by Crowding
Hay or Straw added to TMR’s

- Chopped Dry Hay (1 kg) or Straw (0.3 kg) goes a long way in decreasing sub-clinical acidosis. It is especially important in early lactation.
- Provides a consistent fiber source when silage particles, moisture and quality may vary and different people are mixing the TMR each day.
- Fairly Easy to Purchase; Processed Hay is Now Available
2. Using the Right Starch Sources to Avoid Sub-Clinical Rumen Acidosis
Non-Fiber Carbohydrate (NFC = \[100-\%NDF+\%CP+\%Fat+\%Ash\])

**VFA Produced**

- Propionate
- Lactate
- Acetate

**Fermentation Time**

- Sugars: \(<1 \text{ hour}\)
- Starch: \(2-10 \text{ hours}\)
- Beta-Glucans: \(2-10 \text{ hours}\)
- Galactans
- Pectins
Too Much Fast Fermenting Starch Yields Rumen Acidosis

Source:
- Wheat
- Barley
- Oats
- Corn
- Sorghum

Form:
- Steam-Flaked
- High Moisture
- Dry Ground
- Dry Rolled
- Dry Whole

Allen, 1991
Rumen pH of Cows Fed Corn vs. Barley in a TMR

How Many Hours Is pH below 6.0?

Yang et al., 1997
Rapidly and Slowly Digestible Starches

- Rates of Starch Digestion Are Often Calculated Based on Total Rumen Starch Digestion After 18 Hours in the Rumen.
- BUT.... Starches Don’t Usually Ferment At a Uniform Rate in The Rumen
- Barley and HMSC - Contain More Rapidly Digestible Starch
- Cornmeal - More Slowly Digestible Starch
Starch and Sugar Digestibility

% of Total Starch and Sugar Digested

Time (Hours)

0 2 4 8 18

0 20 40 60 80 100

- Fast Digest Grain
- Slow Digest Grain
## In Situ Starch Degradability
(Roe (de Ondarza), 1994)

<table>
<thead>
<tr>
<th></th>
<th>2 Hour Starch + Glucose (%DM)</th>
<th>Slow Starch (%DM)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cornmeal</td>
<td>21.27</td>
<td>48.41</td>
</tr>
<tr>
<td>Barley</td>
<td>24.42</td>
<td>26.59</td>
</tr>
<tr>
<td>HM Ear Corn</td>
<td>29.92</td>
<td>32.58</td>
</tr>
<tr>
<td>Corn Gluten Feed</td>
<td>13.04</td>
<td>5.43</td>
</tr>
<tr>
<td>Corn Silage</td>
<td>15.07</td>
<td>15.07</td>
</tr>
</tbody>
</table>
3. Maximizing Rumen Microbial Amino Acid Synthesis

Optimizing Rumen Efficiency
Blending Sugars and Starches Synchronizes Nutrient Supply

A Rumen Balancing Act Goes On Each Minute of the Day
The Rumen Microbes Want An Ideal Ratio Every Minute
Use of Protein and Carbohydrate by the Rumen Bacteria

Russell, 1988
Hourly Carbohydrate, Protein, and NPN Availability

- Varies with Fermentation Rates
- Varies with Feeding Pattern and Feeding Frequency

**Cornell Model: Steady State Model**
- Predicts Nutrients Fermented Each Day
- Assumes Constant NFC:Peptide Ratio

**Within-Day Model is Needed**
Hourly Fermentation of Protein, Nitrogen and Carbohydrate

Roe (de Ondarza), 1994

3.2:1 NSC:DIP
Protein and Carbohydrate Fermentation in the Rumen

- Cornmeal: 16 Hours
- Soy: 14 Hours
- High Moisture Corn: 10 Hours
- Canola: 8 Hours
- Sugars: 1 Hour
- Urea (SIP): 1 Hour

Synchronization Makes Bugs!
Simple Sugars

General Recommendation = 4-6% of the DM

- Help Provide Needed Energy At the Right Time In Relation to Starch & Fiber In the Ration
- Increase Microbial Protein Production
- Reduce Nitrogen Wastage
- Decrease Undigested Corn in the Manure
- More Milk Response When the Ration Contains Fewer Fast Digestible Starches
**Sweet Lac™ - Milk Yield (Tully, NY)**

 Avg. milk response over 57 days = 1.5 kg

**Key Point:** Cows over 41 kg respond to Sweet Lac
Fine-Tuning Ration Synchrony

Lady Balance for Sugars, Fast Digestible Starches, and Slowly Digestible Starches

General Recommendations:
- 4-8% DM Fast Digestible Starch Source
- 4-6% DM Sugar

Advanced Methods and Models Need to Be Developed To More Accurately Predict Starch Fractions and Microbial Needs for Different Starches
4. Maximizing Fiber Intake and Digestibility
How Does Fiber Help The Cow?

- Stimulates Chewing & Saliva Production
- Saliva Neutralizes Acids and Increases Rumen pH
- Forms Rumen Mat Which Slows Passage of Grains and Increases Their Digestibility
- Facilitates Movement of Rumen Contents and Absorption of Acids

15% of Ration Particles > 1.5 in (3.8 cm)

50-60% of Cows should be Chewing
How Does NDF Hinder the Cow?

Rumen Fill Limits Intake

High-Producing Cows With a Well-Functioning Rumen Are Limited In Forage Intake By the BULKINESS of the Fiber which Fills up the Rumen.

This Bulkiness is best estimated by the Forage NDF Content & NDF Digestibility.
In the Past, only NDF Content was considered....

- Balanced Rations for NDF or Forage NDF
- More NDF in Forages Meant Less Forage Could Be In the Ration
- Forage:Concentrate Must Decrease if Production is to be Maintained on Higher NDF Forages
### 30-Hour *In Vitro* NDF Digestibility Ranges (%NDF)

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
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</thead>
<tbody>
<tr>
<td>Corn Silage</td>
<td>35.6 - 69.9</td>
<td></td>
</tr>
<tr>
<td>Legume Hay</td>
<td>23.2 – 59.2</td>
<td></td>
</tr>
</tbody>
</table>

*Dairy One Forage Lab – 2000-2004*

*In Vitro* NDF Digestibility is poorly related to the Concentration of NDF, ADF, and CP
Rate of NDF Digestion

- Legumes have less total NDF but due to greater lignification, have lower NDF digestibility.
- Grasses have less lignin and large ranges in maturity contributing to a large range in NDF digestibility.
- As plants mature, fiber content increases and NDF digestibility decreases.
- Warmer weather promotes lignification and reduces NDF digestibility.
- Light (or daylength) promotes photosynthesis and glucose production, having a positive effect on overall plant digestibility.
Effect of NDF Digestibility on Intake and Milk Production (Oba and Allen, 1999)

- Analyzed data from 13 sets of Forage Comparisons in the Literature
- NDF Concentration = Covariate
- One unit increase in NDF digestibility
  - Increase of 0.37 lbs (0.17 kg) in DMI
  - Increase of 0.55 lbs (0.25 kg) in 4% FCM

Lbs of NDF & Its Digestibility Affect Forage Intake
BMR Corn Silage Study
(Oba and Allen, 1999)

- BMR Corn Sil (44.6%)
  - NDF Dig = 49.1%
  - Alfalfa Silage (11.2%)
  - NDF = 30.8%
  - DMI = 25.6 kg*
  - Milk = 41.7 kg*
  - Fat = 3.44%
  - 4% FCM = 38.2 kg*

- Reg Corn Sil (44.6%)
  - NDF Dig = 39.4%
  - Alfalfa Silage (11.2%)
  - NDF = 31.6%
  - DMI = 23.5 kg
  - Milk = 38.9 kg
  - Fat = 3.46%
  - 4% FCM = 35.7 kg

Same Diets Just Switched Corn Silage
NDF Digestibility for the High-Producing Cow

- **Affects Ration Energy Content**
  - Standard forage tests assume a digestibility value for NDF when NE\textsubscript{i} or TDN is calculated
  - Increasing NDF digestibility increases energy

- **Dictates Ration Physical Fill**
  - Increasing ration NDF digestibility can increase Forage and DM Intake

- **Impacts Acidosis**
  - Highly Digestible NDF may leave the rumen quicker causing more acidosis if not accounted for
  - If Grain Levels are dropped, Highly Digestible NDF can reduce acidosis & increase milk
How Much Forage NDF is Best for the Cow and for Making $$?

- Enough Total NDF and Chewable NDF to fight Acidosis
- Maximize Forage Intake
- Provide Enough Ration Energy for Maximum Milk
- Ideal Level Varies
Forage NDF Level

21%  Long Forage Particles  26%

High-Fiber Byproducts

TMR

Slug Feeding

Fast Degradable Starch

Buffers

High Fiber Digestibility

Added Fat

Variation in Forage DM & Quality
Using Highly Digestible Forages

- Balance for Kg of Digestible NDF
  - High Cows Ration ~ 24-26% Forage NDF
- Reduce Grain Levels
- Increase Predicted Dry Matter Intake
- Maintain Good Effective Fiber Levels
  - Adding Hay or Straw Helps
- Watch the Manure & Cud-Chewing
- Acidosis Signs? .. Reduce Grain More

Allocate Highly Digestible Forages to Early Lactation Cows
What if Forage NDF Digestibility is Poor?

“Sub-tropical forages”

Use Commodities, such as beet pulp and cottonseed, to help meet energy requirements

Control NFC -- 36-38%

Minimize Forage NDF -- 21-23%

Farm Forages Must Provide Enough Effective Fiber (1-1.5 kg Hay is Great)
Non-Forage Fiber Sources

- Rapidly Digested NDF and Pectin
- Yields Acetate
- Less Propionate and Lactate
- Less Acidosis
- Contain Little Effective Fiber
5. Ration Balancing With High Feed Prices
### CPM-Dairy Nutrient Recommends

<table>
<thead>
<tr>
<th>Nutrient</th>
<th>Min, %DM</th>
<th>Max, %DM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sugar</td>
<td>4</td>
<td>6</td>
</tr>
<tr>
<td>Starch</td>
<td>21</td>
<td>27</td>
</tr>
<tr>
<td>Soluble Fiber</td>
<td>4</td>
<td>8</td>
</tr>
<tr>
<td>Ferm NDF</td>
<td>10.5</td>
<td>12</td>
</tr>
<tr>
<td>peNDF</td>
<td>22</td>
<td>24</td>
</tr>
</tbody>
</table>

24-26% Starch is Typical in Northeast U.S.
What Changes with High Corn Prices?

- Higher usage of fast degradable starch
- Always using finely ground corn (no passage in manure acceptable)
- Higher usage of soluble fiber especially pectin (8-10% DM)
- More dietary sugars (6% DM)
- Less overall starch (21-23% DM)
- More fermentable NDF (11-12% DM) and More forage NDF (25-27%)
Optimize starch digestion from corn silage

- 0.75 inch (1.9 cm) Theoretical Length of Cut, 2-3 mm roller clearance
- Penn State Particle Size Separator
  - 10-15% top screen
  - 50+ % second screen
  - < 35% bottom screen and pan

All kernels must be crushed, especially silage > 33% DM

Grant, 2008
Corn Silage sent to CVAS in October, November, and December had significantly less (P<0.05) available starch than samples sent during March through September.
Grain Particle Size

- 67% of Cornmeal Should Pass Through a Kitchen Flour Sifter (~ 1.18 mm)
- This Equates to an average Particle Size of 1100 Microns

High-Moisture Corn
- 28-32% Moisture - Roll Before Feeding
- >32% Moisture - Roll Less
- <25% Moisture - Grind Before Feeding
What to Watch when Lowering Starch:

- Manure – can be stiffer with insufficient starch in the diet
- MUN’s – may increase if not enough dietary starch
- Milk protein – may decrease if microbial yield is reduced
- Milk production

Always Lower Dietary Starch Gradually
The Big Picture...

The Basics:

- Cow Comfort
- Heifers
- Fresh Cows

Making the Most Of the Rumen:

- Intake
- Fiber Digestibility
- Synchrony
- Rumen Health

Amino Acids, Milk, & Milk Protein