Balancing Carbohydrates for High Producing Cows

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With increasing milk production and emphasis on milk protein, meeting the nutrient needs of dairy cows is becoming a greater challenge. A balanced ration provides the correct amounts of nutrient for maximal microbial growth and end product yield (volatile fatty acids and microbial protein) plus undegraded nutrients (protein, carbohydrates, and fats) meeting the cow's productive needs (milk, growth, reproduction, and maintenance). Carbohydrates make up 70 percent of the ration and serve as the primary source of energy for lactating cows. This paper will discuss structural, non-structural, and functional carbohydrate components of the dairy ration (Table 1).

Table 1. Carbohydrate Fractions (Sniffen, 1988)

Fractions	Contains	Digestion Rate
Neutral detergent fiber	Hemicellulose, cellulose, pectin and lignin	Slow to moderate
Acid detergent fiber	Cellulose and lignin	Slow
Cell solubles	Starch and sugar	Rapid
Nonstructural carbohydrate	Starch, pectins, and sugars	Rapid to moderate

Structural Carbohydrates

Structural carbohydrates or cell wall carbohydrates represent the fibrous component in the ration. The rate of forage degradation in the rumen will depend on the variety, age, and season of harvest (Table 2). Concentrate fiber will vary based on particle size and type of feed.

Definitions of field measures of structural carbohydrate are are described below:

- Crude fiber consists of the portion of feed not soluble in an acid or alkaline solution. It is the current fiber measure for commercial feeds and is guaranteed on feed tags. Crude fiber does not measure all fiber fractions in feeds.

- Acid detergent fiber (ADF) uses an acidic detergent to solubilize cell fractions (cell solubles, pectins, and hemicellulose). ADF consists of cellulose, lignin, unavailable protein (heat-damaged forages, for example), and insoluble ash.

- Neutral detergent fiber (NDF) represents the residue after treating feeds with a neutral detergent and consists of ADF plus hemicellulose.

Table 2. Ruminal Rate of Degradataion of NDF (Tamminga, 1989)

Feed	NDF (%)	Rate	Bulk
Young grass	40	Very high	Low
Alfalfa hay	42	High	High
Grass silage	50	Medium	Medium
Corn silage	45	Medium	High
Grass hay	55	Low	High
Straw	70	Very low	Very high
Beet pulp	50	High	Low
Brewers grain	62	Medium	High
Soy hulls	55	High	Low
Cottonseed hulls	28	Medium	High

ADF is a useful index of digestibility or energy concentration of a feed. It can be accurately analyzed in most labs with a repeatable procedure. Levels of ADF for dairy cows are listed in Table 3. NDF can be used as an index of bulk or fill in a dairy ration. Optimizing NDF should maximize dry matter intake. Analytical procedure for NDF are not as clear or easy to run as ADF. NDF can be used to estimate forage intake. Wisconsin workers suggest 21 percent NDF from forage NDF sources or .9 percent of the

Table 3. Carbohydrate Guidelines for Dairy Cows at Various Stages of Lactation (Hutgens, 1990)

	Stage of lactation		
Carbohydrate	Early	Middle	Late
Crude fiber	15	17	19
ADF	19	21	24
NDF	28	32	36
NFC	40	36	32

cow's body weight from forage NDF sources. Examples of both methods are illustrated below with a forage NDF value of 45 percent.

- Method One: 21% NDF from forage NDF
  21% NDF ÷ 45% forage NDF (.45) = 47% forage in the ration dry matter
  50 lb. DM intake x 47% forage = 23.5 lb. forage D.M.

- Method Two: .9% weight
  1300 lb. cow x .9% (.009) = 11.7 lb. forage NDF
  11.7 lb. forage NDF ÷ 45% forage NDF (.45) = 26 lb forage D.M.

Another guideline from Cornell is 1.2 percent of a cow's body weight as total NDF from forage and grain. This value will result in similar levels of forage NDF as the Wisconsin guideline. Total NDF guidelines are listed in Table 3.

Functional Fiber

Dairy cows must maintain a forage mat in the rumen and maintain rumination. Effective or functional fiber refers to the physical form or length of fiber that stimulates cud chewing. Guidelines for functional fiber are listed below.

- Five pounds of forage dry matter over 1½ inches in length.

- Haylage which contains 15 to 25 percent of forage particles over 1½ inches in length.

- Ten hours of eating and ruminating time per day.

- An average of 12 to 15 minutes of chewing time per pound of ration dry matter consumed.

Another method to measure fiber form suggested by Wisconsin workers was the roughage value of feed (the fraction of particles retained on 1.18 mm sieve). Estimates of roughage value assume that only NDF larger than 1.18 mm contributes to chewing activity regardless of source or fragility (Table 4). This approach allows the user to adjust forage NDF. For example, if a herd needs 11.7 pounds of forage NDF and the haylage had a roughage value of .80, 11.7 pounds would be divided by .80 resulting in 14.6 pounds of forage NDF. Forage labs in the future will provide dairy farmers and nutritionists with a similar value to decide if long hay, more haylage, or longer chopped silage are needed.

Table 4. Estimates of Roughage Value (Sniffen, 1988)

Feed	NDF (%)	Fraction on 1.18 mm sieve (%)	Roughage Value Unit
Standard	100	1.00	100.0
Grass hay	65	.98	63.7
Legume hay	50	.92	46.0
Legume silage (coarse)	50	.82	41.0
Legume silage (fine)	50	.67	33.5
Legume pellets	50	.10	5.0
Corn silage	51	.81	41.5
Brewers grain	46	.18	8.3
Soybean hulls	67	.03	2.0

Table 5. Ruminal rates of starch degration (adapted from Tamminga, 1989)

Feedstuff	Starch (%)	Degradation Rate	NFC (%)
Shelled corn, dry and coarse	70	Low	74
Shelled corn, dry and fine	70	Moderate	74
Shelled corn, wet and fine	70	High	74
Wheat, ground	65	Very High	71
Barley, rolled	58	High	55
Oats	44	High	47
Corn gluten feed	35	High	27
Wheat midds	25	Very High	36

Non-structural Carbohydrates

Non-structural carbohydrate measures the starch and sugars which are fermented to propionic acid. If the fermentation is too rapid, lactic acid can be produced leading to acidosis. The amount of starch and rate of starch degradation depends on source, physical processing, fermentation, and heat treatment (gelatinizing). Starch assays are expensive, time consuming, and not commercially available.

Non-fiber carbohydrate (NFC) represents pectins (found in legumes, beet pulp, and other feeds) plus starch and sugars. Other terms to describe NFC include soluble carbohydrate and rumen available fermentable carbohydrate. NFC can be calculated by the following equation.

$$NFC = 100 - (NDF + \text{crude protein} + \text{ash} + \text{fat})$$

NFC values can be calculated from commercial feed tests results. The recommended level of NFC can be expressed as a percent of body weight and rate of NFC degradability (Table 6). Other guidelines for NFC are listed in Table 4. New York workers suggested the following management guides to manipulate NFC in dairy rations.

- Balance the type and amounts of NFC.
- Switch to total mixed rations (TMR).
- Alter forage to concentrate ratios to balance NDF and NFC fractions.
- Evaluate particle size of feeds to estimate rate of degradation.
- Encourage frequent feeding to stabilize the rumen pH and environment.
- Plan feed sequence to stimulate rumination, improve saliva production, and form a forage mat.
- Match protein degradation to NFC degradation patterns.

Table 6. NFC guidelines in early lactation rations (Sniffen, 1988)

Rate of Degradation	Amount (% B.W.)	Feeds
Slow Rate	1.1 to 1.4	Ear Corn, Brewers Grain
Medium Rate	1.0 to 1.1	H.M. Corn, Beet Pulp
Rapid Rate	.8 to 1.0	Wheat, Barley

Rumen Feed Additives

Rumen buffer (sodium bicarbonate) increased milk yield by 2.2 pounds of 3.5 percent fat-corrected milk (based on 24 research studies with 2087 cows). Buffers can increase dry matter intake and stabilize rumen pH above 6 with the optimal response in early lactation cows (fresh less than 100 days). The following products can be used.

- Sodium bicarbonate is an effective buffer fed at the rate of .25 to .5 pounds per day.
- Sodium sesquicarbonate is a buffer and alkalinizing agent fed at the rate of .25 to .5 pounds per day.
- Magnesium oxide is an alkalinizing agent and source of magnesium fed at .1 to .2 pounds per day.

Sodium bentonate is not a buffer, but can change the rate of passage and improve ion exchange capacity in the rumen. Limestone (calcium carbonate) does not have buffering effect in the rumen. Potassium carbonate can be used as a buffer, but it is more expensive per pound than sodium bicarbonate and requires .6 to .9 pounds per cow per day.

Yeast and yeast cultures can improve the rumen environment by stimulating fiber digesting bacteria, reducing lactate production, and maintain higher rumen pH. A reduction of rumen methane and ammonia can improve rumen efficiency. Rations with higher levels of soluble NFC provided the greatest response in milk yield.

Probiotics are relatively new areas of research and field use. These products are primarily microbial cultures or fermentation products added to the ration to balance or replace unfavorable organisms. Antibiotics destroy undesirable organisms; probiotics compete against undesirable organisms. Probiotics have been successfully fed to cattle under stress conditions such as in off-feed situations, acidosis, early lactation, and scouring animals. A wide variety of commercially available organisms is available in pure culture or a combination (National Feed Ingredient Association listed 15 strains in 1982). These products are live organisms and must be handled to maintain viability. Research results should be reviewed to determine product success and individual farm conditions assessed prior to probiotic supplementation.

Fungal additives contain enzymes that can digest and cleave lignocellulose bonds (fiber). Improvements in fiber breakdown and protein synthesis in the rumen has been reported from feeding fungal extracts. Milk production responses (3.1 pounds of milk) and reduced heat stress (decreased rectal temperature and respiratory rate) have been reported.

Summary

Carbohydrate level, form, and type have dramatic effects on rumen fermentation and cow performance. Rumen pH should range from 6.2 to 6.8 allowing for optimal microbial growth and digestion. The correct rumen environment will maximize microbial protein yield, produce the desired rumen volatile fatty acid patterns, and digest fibrous feed ingredients. Some undegraded NFC (such as starch) is desirable as it can be digested in the small intestine providing a source of blood glucose. High levels of undigested starch can cause fecal pH values below 6 and a loss of nutrients. Goals for a balanced ration focusing on carbohydrate include:

- Maintaining a forage mat in the rumen to stabilize the rumen environment and rate of passage.
- Maximizing digestible organic dry matter as a substrate for microbial growth.
- Balance the amount of rumen degradable and undegradable NFC (barley or corn for example) and ADF and NDF levels.
- Match protein sources to complement the carbohydrate sources (urea with molasses, high moisture corn with soybean meal).

Manipulating rumen volatile fatty acid patterns (60-65 percent acetate, 15 to 20 percent propionate, and 10 percent butyrate) through stabilizing rumen pH, feeding patterns, and bunk management.

References

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