Making Milk with Forage: A New Era

Rick Grant, William H. Miner Agricultural Research Institute

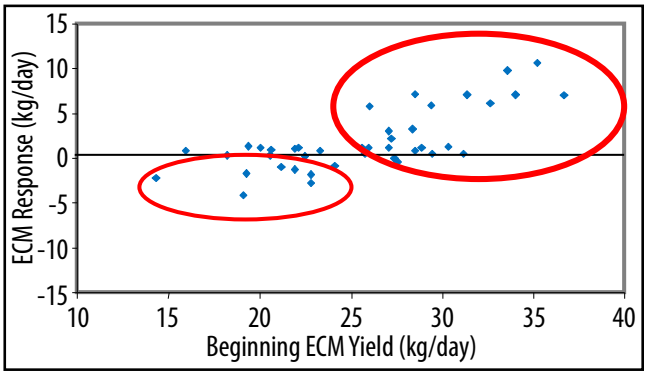
When dairy cows consume high quality forage, we can expect higher milk component output, fewer metabolic disorders, healthier feet, greater longevity, less purchased grain, and overall greater income-over-feed-cost. There is a well-established relationship between forage NDF digestibility and dairy cow performance. For each one percentage-unit increase in NDF digestibility, we should see 0.39 lb/day more dry matter intake and 0.55 lb/day more 4% fat-corrected milk.

Relative response to NDF digestibility is also a function of individual cow's milk production level and lactation stage. Figure 1 shows higher corn silage NDF digestibility response when fed total mixed rations (TMR) containing either hybrid. Overall, cows responded modestly to higher NDF digestibility. Higher producing cows responded more positively than lower producing cows, that did not respond or even responded negatively, to greater forage NDF digestibility.

To Make Milk, We Need to Understand Fiber Digestibility and Indigestibility

Fiber digestibility and indigestibility are critical factors when assessing forage quality and formulating diets. Digestion characteristics of NDF influence feeding and rumination behavior, rate of particle breakdown, rumen fiber turnover and fill, dry matter intake, and overall efficiency of milk component output. Traditionally, nutritionists have focused on measures of fiber digestibility, but recently the focus has included indigestible fiber due to its importance in setting the extent of and influencing the rate(s) of fiber fermentation in the rumen. In nutritional modeling, indigestible NDF is required as the end point for fermentation to allow accurate estimation of the potentially digestible NDF fraction and its rate(s) of digestion. Dr. Dave Mertens has coined the term "undigested NDF (uNDF)" as the laboratory measure (typically in vitro or in situ) of indigestible NDF at a specified fermentation time. The current recommended method requires 240 hours of in vitro fermentation using a Tilley-Terry system (i.e., test tube artificial rumens).

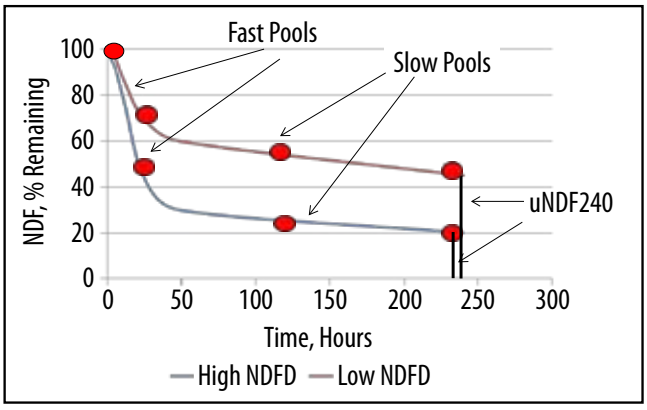
Figure 1. Difference in energy-corrected milk (ECM) response for cows fed low vs. high NDF digestibility corn silage hybrids as it varies with milk production level (Ivan et al., 2004. J. Dairy Sci.88:244-254).



To date, we have used a 2-pool model of rumen NDF digestion – potentially digestible NDF and indigestible NDF. With the advent of the 3-pool model for NDF digestion we are entering a new era in terms of ability to accurately formulate diets and predict cow response to forage – whether a high-forage diet or strategic use of smaller amounts of forage. The three pools are fast-digesting NDF, slow-digesting NDF, and uNDF measured at 240 hours of in vitro fermentation. Potentially digestible NDF is NDF minus uNDF. Figure 2 illustrates these three fractions for typical high and low NDF digestibility forage.

Fast and slow NDF exists in all forages: legumes, grasses, corn silage, and other grain-containing forages. The bottom line is high NDF digestibility forages are associated with more fast-pool NDF, less slow-pool NDF, and less uNDF. Forage labs are beginning to measure these fractions routinely. Being able to better characterize the actual digestion profile of forage fiber will allow us to do a better job of formulating diets.

Figure 2. NDF fermentation curves illustrating time points currently recommended for estimating fast, slow, and undigested NDF for an example high and low NDF digestibility forage.



How Much NDF Can the Dairy Cow Consume – and How Long Does It Take?

Consumption of NDF by dairy cows is related to rumen fill and intake potential of a forage or ration. Optimal NDF intake occurs at the point of maximum milk production and is ordinarily ~1.25 ± 0.10% of body weight (BW) per day (mean ± standard deviation) for a cow in mid to late lactation. It is important to understand that optimal NDF intake is not maximum NDF intake, but instead NDF intake maximizing milk production.

We also must appreciate the impact forage NDF characteristics have on eating and ruminating time. In Miner Institute studies, we have observed up to an hour per day difference in eating time between cows fed lower forage, high NDF digestibility diets vs. higher forage, lower NDF digestibility diets. Feeding brown midrib vs. conventional corn silage has resulted in a half-hour per day difference in eating time.

Higher forage diets with slower fermenting forage NDF take cows longer to process. There are important time budget challenges when cows are overstocked at the feed bunk, especially for younger cows that cannot process forage fiber as effectively as mature cows. We must be sure feed bunk and pen management provide sufficient time for cows to eat and effectively ruminate the forage in the diet as NDF quality and amount vary.

Current Insights into NDF and uNDF Intake Targets

At Miner Institute, we have evaluated diets with a substantial range in corn and haycrop silage source and amount. Diets have ranged 36-55% corn silage (DM basis), have contained conventional vs. brown midrib corn silage that varied by 10%-units in NDF digestibility, and some diets have contained up to 10% added chopped straw to maintain chewing activity as forage percentage was reduced from 52 to 39% (DM basis). Overall, diets contained 39-68% total forage.

Based on these studies, here are some preliminary targets and ranges for NDF intake applicable to highly productive dairy cows (~55 lbs/d dry matter intake, and 90-100 lbs/d milk production) fed diets based on corn silage, haycrop silage, and chopped dry alfalfa hay. Note all NDF values are expressed as amylase-modified, sodium sulfite-treated, and ash-corrected NDF:

- Maximum dietary NDF intake is ~1.47% of BW (range of 1.26-1.47%).
- Maximum rumen NDF is ~1.28% of BW.
- Range dietary uNDF intake is 0.30-0.48% of BW.
- Range in uNDF mass in rumen is 0.48-0.62% of BW.
- Ratio of rumen uNDF/intake uNDF is ~1.60 regardless of diet.

Cows respond predictably to NDF and NDF digestibility. We are learning the ratio of uNDF in the TMR and the rumen appears to be constant over a fairly wide range of diets. We understand the cow's intake response to NDF and how it varies with NDF digestibility. We must better appreciate the impact of NDF amount and digestibility (or indigestibility) on the length of time it takes for a cow to process her daily allotment of forage NDF. These relationships are a starting point to begin implementing what we have learned recently about fiber digestibility in the field.

Perspectives

The goal of current research is to optimize the cow response to forage NDF whether the situation is a high-forage diet or more strategic, limited use of forages. Understanding the role of NDF digestibility and indigestibility is critical for predicting cow response.

We are quickly entering a new era in our ability to measure forage NDF digestion characteristics and to accurately model cow response to forage quality. The uNDF fraction is the "ballast" that serves as an intake constraint. The relative proportions of fast and slow NDF determine the flux of NDF through the rumen. In particular, we believe uNDF plus slow-NDF govern rumen space available and consequently dry matter intake. The proportion of fast and slow NDF within a forage or diet determines the relationship between digestion rate, rate of particle breakdown, and passage from the rumen. We should be able to optimize efficiency of feed use by identifying the optimal ratio of fast-NDF to slow-NDF to uNDF. Over a fairly wide range of dietary forages, the ratio of rumen to intake uNDF seems to be ~1.60. In other words, uNDF in the rumen is ~1.6 times the uNDF in the diet. If the cow eats more uNDF, then there is more uNDF in the rumen, up to a maximum amount.

We are close to developing an improved system for accurately determining intake and rumen fiber turnover based on assessment of fast-NDF, slow-NDF, and uNDF. Stay tuned - it is an exciting time to be feeding forage to dairy cows!