FIBER IS COMPLICATED

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INTRODUCTION

Over the last several years, multiple papers have been presented at this conference regarding new analytics for NDF. Van Amburgh and Van Soest (2003) continued down a path where potentially digestible (pdNDF) pool size and degradation rate (kd) were calculated from the lignin x 2.4 relationship. Raffrenatio et al (2010) introduced the multi-point NDF *in vitro* system to estimate pools and rates. Van Amburgh et al. (2015) highlighted the importance of the ash correction due to soil contamination in NDF analysis. Presentations have also introduced the concept of u240 %BW in relation to DMI (Cotanch et al (2014)) and how this value is variable (Zontini et al (2015)). Throughout these steps, the commercial laboratories and software providers have had to implement these changes and explain the impact on results everyone has been accustomed to. During this time, we have found there is much confusion regarding all these updates.

Thus far, data that has been presented at this conference has been development data. The commercial laboratories have been providing aNDFom, u30, u120 and u240 for over 18 months now. In an attempt to further explain this complex topic, data from one laboratory (DairyLand) was obtained from for this evaluation. Over 65,000 sample results containing standard chemical analysis, aNDFom, u30, u120, u240, RFV, RFQ, and NRC2001 TDN were shared. Feeds included were: alfalfa (hay and silage), grass (hay and silage), grass/alfalfa mixes (hay and silage), corn silage (fresh, conventional, BMR), and small grain crops (wheat, barley, rye, triticale). Results are from both wet chemistry and, primarily, NIR analysis.

The objectives of this paper are: 1. Review the transition from aNDF to aNDFom; 2. Present a simple model illustrating NDF kinetics; 3. Present an evaluation of various unavailable NDF pool methods; and 4. Illustrate an interaction between aNDFom and u30, u120, and u240.

aNDF VERSUS aNDFom

In terms of software implementation, this was simple requiring a few label changes. Explaining the change and its impact has been more challenging. Soil and silica that is on/in the plant is not soluble in aNDF solution. This results in inflated aNDF results when expressed on a dry matter basis. Simply ashing the aNDF residue and reporting the results on an organic matter basis addresses this. In general, this reduces aNDF results 1-2 units. However, depending upon harvest, wind (dust contamination), irrigation (especially flood irrigation), and flooding results can be 4-20 units different. While directly changing aNDF values, there are two other values that change: NFC and soluble fiber.

This is because NFC and soluble fiber are calculated by difference. The ash value does not change as the soil/silica is already included in standard ash methods. The calculations for NFC and soluble fiber are:

NFC = 100 – CP – Fat – Ash – aNDFom
Soluble fiber = NFC – silage acids – lactic acid – other organic acids – sugar – starch

Therefore, the organic matter adjustment reduces aNDF content, increases NFC and soluble fiber, and results in higher ME and MP predictions due to the increased NFC/soluble fiber.

MODELING aNDFom KINETICS

A simple two-pool model was developed in Vensim (2010) to illustrate NDF kinetics. An example diet consisting of 28% aNDFom, 60% fast pool (15%/hr kd), 20% slow pool (2%/hr kd), and 20% uNDF was offered to the model as four equal meals throughout the day. Passage rate was assumed to be 1.5%/hr and the model was simulated over 480 hrs.

Figure 1 illustrates the behavior of uNDF (u240 grams) from this simulation. Given that uNDF can only escape the rumen via passage rate, this simulation approaches a steady-state of 4,250 grams after 240 hours. Similarly, a steady-state passage of 65 g per hour is obtained, equal to the 1.5% kp. Figure 1 (right panel) is the behavior when only one meal is fed representing the same total daily aNDFom intake. It takes over 300 hours (12.5 days) for all the uNDF to escape the rumen. Putting this in perspective, it is one of the reasons high fill (typically straw) close-up diets can be successful. The DMI depression around parturition, resulting in less rumen fill, is partially mitigated by uNDF remaining in the rumen.

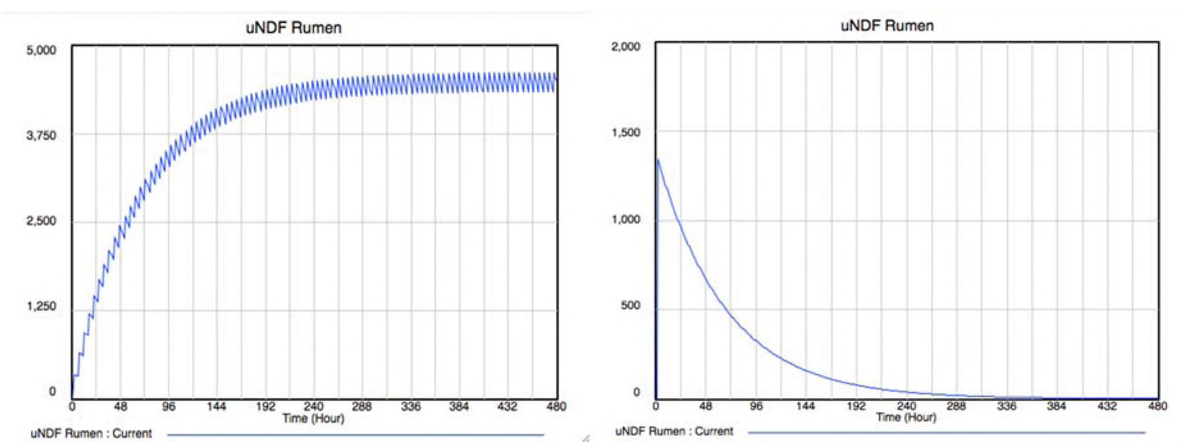

Figure 1. Ruminal uNDF content, grams. (left panel) multiple meals per day, (right panel) single meal per day.

Slow pool aNDFom exhibits similar behavior as illustrated in Figure 2. Notice that the high/low range between meals is greater than for uNDF as this pool is subject to both degradation and passage. Passage reached a steady-state of approximately 30 g/hr while rumen levels fluctuated between 1,786 and 2,059 g. Thus, 40 g is degraded per hour.

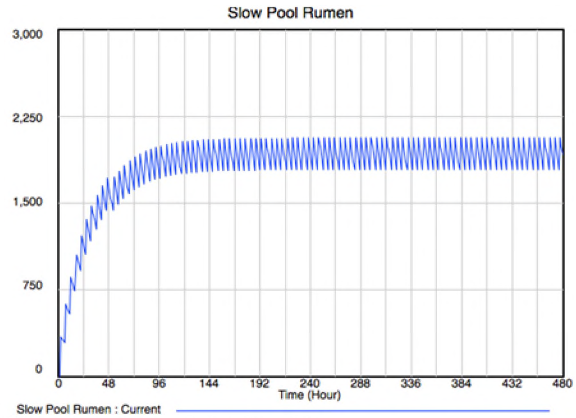

Figure 2. Slow pool aNDFom rumen contents.

Fast pool aNDFom is highly variable in terms of rumen contents, passage, and degradation. As Figure 3 illustrates, there is a large variance with 120 to 254 g degrading per hour and 12 to 25 g escaping per hour. The reason for these variable rates is simply the competition between passage and degradation rates. When maximum amounts of substrate are available (after a meal), higher degradation occurs as it out-competes passage.

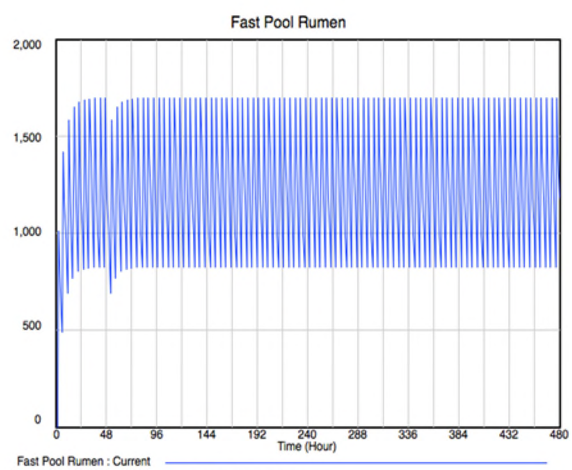

Figure 3. Fast pool aNDFom rumen contents.

Evaluating the fast and slow pools when fed the entire aNDFom amount daily, it becomes clear the difference in aNDFom kinetics. As Figure 4 illustrates, 99% of the fast pool is degraded whereas only 57% of the slow pool is degraded. The fast pool is exhausted by 24 hours whereas the slow pool remains after nearly 144 hours.

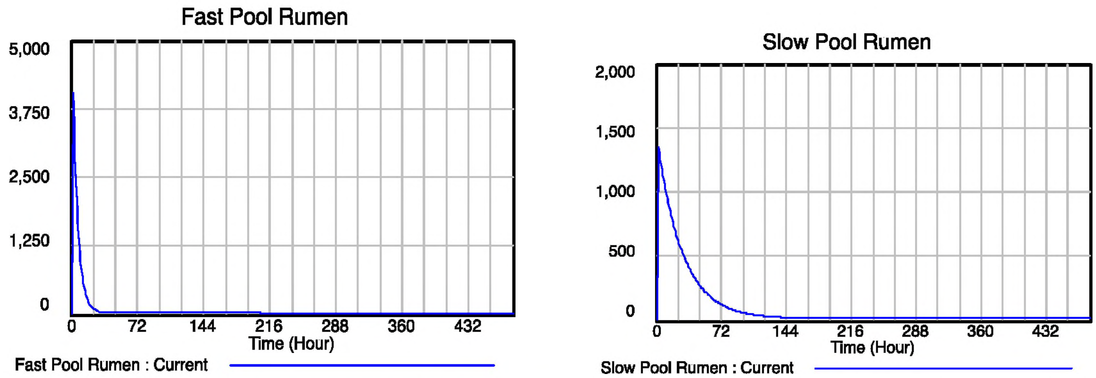

Figure 4. Fast and slow pool aNDFom rumen contents when only one meal per day is fed.

At this point, one may be tempted to conclude that fast pool, and more specifically 30 hr dNDF, is the critical value to evaluate in relation to DMI. While this may be partially true, Van Amburgh and Cotanch (personal communication) have suggested the rumen has a aNDFom capacity of approximately 8 kg. Figure 5 supports this suggestion using this example. As shown, it is the total disappearance (degradation and passage) of the three pools that are important. One must also remember that particle size and species play large roles in how these pools reach the required particle size (geometrical mean particle size of approximately 1.18 mm) to escape. On-farm observations from 2017 suggest harvesting grass silage at 12 mm vs 19 mm TLC increased DMI and maintained milk production when feeding alfalfa and grass silage compared to all alfalfa silage.

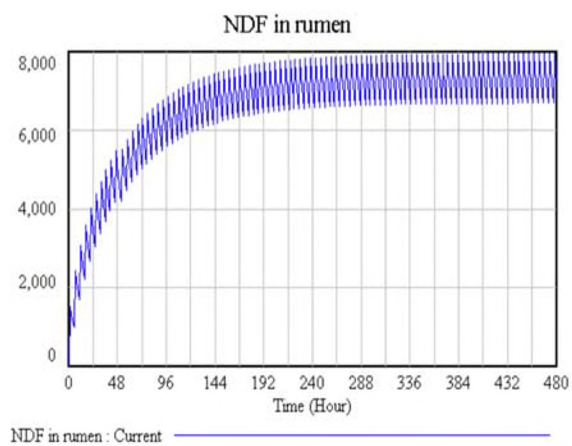

Figure 5. Total aNDFom rumen contents.

uNDF COMPARISONS

uNDF (%NDF) was calculated three different ways: 1. u240; 2. Lignin x 2.4; and 3., the surface area relationship with lignin used by the 2001 Dairy NRC (2001). Figure 6 illustrates the relationship between lignin x 2.4 and the surface area relationship. While in general good agreement, lignin x 2.4 has a wider range and deviates from the surface area relationship when greater then 60%. The correlation coefficient was 0.99 and distributions of each are a very similar bimodal pattern.

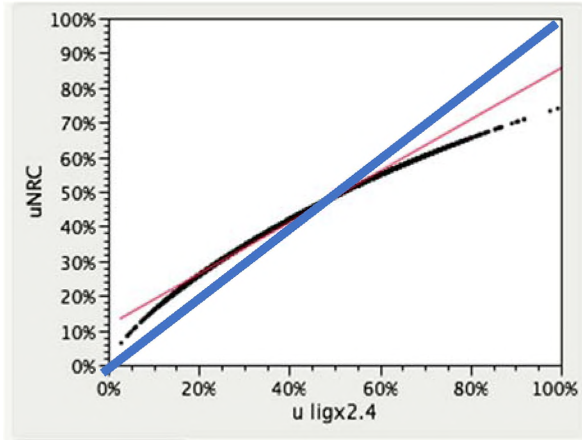

Figure 6. Relationship between lignin x 2.4 and lignin/aNDFom surface area, %aNDFom. The red line is best fit linear model and the blue line is the unity line.

The high correlation of lignin x 2.4 and the surface area relationship is in contrast to their relationships with u240 (Figure 7). The lignin x 2.4 relationship shows a significant linear bias; however, there is also a wider range when compared to the surface area relationship and u240. Correlation coefficients for both are 0.82 with u240. Regardless, these simple relationships are insufficient in accounting for the differences in lignin cross linkages that result in uNDF. Neither method was able to adequately account for the significant variation in measured uNDF at 240 hrs as evidence by the poor fit (r-sq < 0.7 for each).

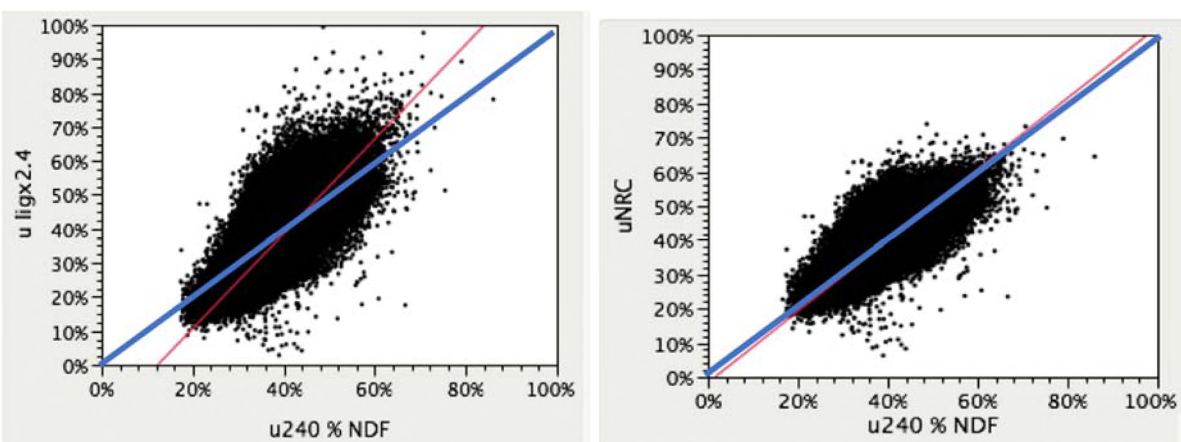

Figure 7. Relationship between lignin x 2.4 and u240 (left panel), and lignin/aNDFom surface area and u240 (right panel). The red lines are best fit linear models and the blue lines are unity.

RELATIONSHIP BETWEEN POOLS AND aNDFom

A simple linear slope was calculated for 0 to 30 hr uNDF (%NDF), u30 (%NDF) to u120 (%NDF), and for u120 (%NDF) to u240 (%NDF). These slopes were used as proxies for the slow pool and a shift from fast to slow pool. The greater the slope between u30 and u120 represents larger slow and u pools. A small (or zero) slope suggests a small, or non-existent, slow pool. An example of a feed that has relatively small slow pool size is alfalfa. Alfalfa is primarily fast pool (leaves) and uNDF (stems).

Species and genetics exhibited different behaviors. Generally, as aNDFom increases, the zero to 30 hr slope decreases. Conversely, the 30 to 120 hr slope increases as aNDFom increases. This suggests the plant is increasing lignin cross linkages resulting in a shift from fast to slow pool aNDFom as the plant matures. Grasses tended to exhibit a greater shift in slopes then other forages. BMR corn silage had a narrower range then conventional hybrids suggesting more aNDFom remains in the fast pool.

Grass hay exhibited very unique behavior with the 120 to 240 hr uNDF slope. There appears to be very little shift from slow to u pool within this classification (Figure 8). This suggests that u240 %BW cannot be used with existing guidelines (~0.35% BW) as it is the slow pool that is more variable for grass based diets.

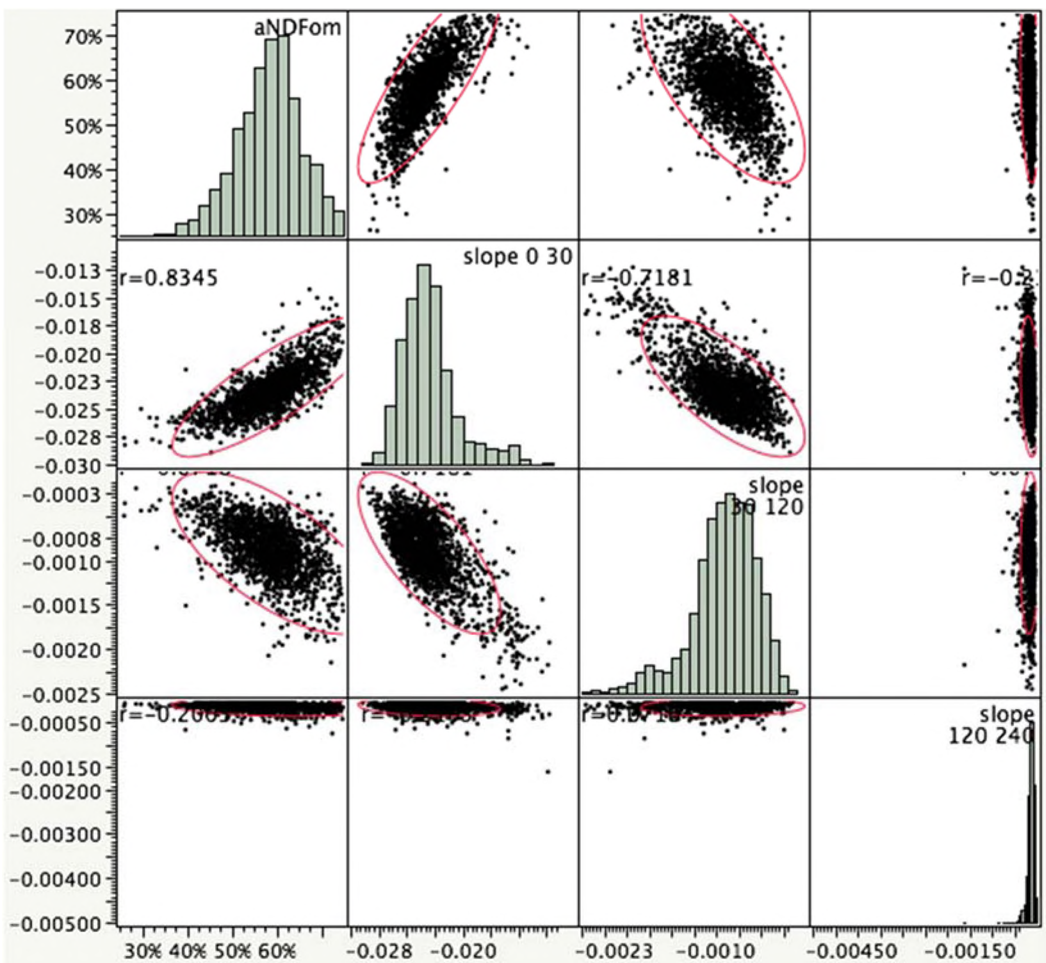

Figure 8. Correlation matrix for aNDFom, 0-30 hr slope, 30-120 hr slope, and 120-240 hr slopes of uNDF for grass hay.

The generic grouping corn silage (a mix of conventional and BMR samples that cannot be split due to sample submission labeling) is representative of small grain silages as well (Figure 9). In addition to the directionality discussed previously, there tends to be a large variance in the 120-240 hr slopes. This is most likely due to environmental conditions (growing degree days and precipitation), soil fertility, and soil drainage the plant is exposed to. Flis et al. (2016) reported significant differences in corn silage aNDFom pools and uNDF. In this study, soils in hydrological class A had 9.9 units lower uNDF. Additionally, BMR hybrids were 6.6 units lower in uNDF. They also reported that precipitation (New York farms) during May and August were highly influential in shifting aNDFom from fast to slow pool.

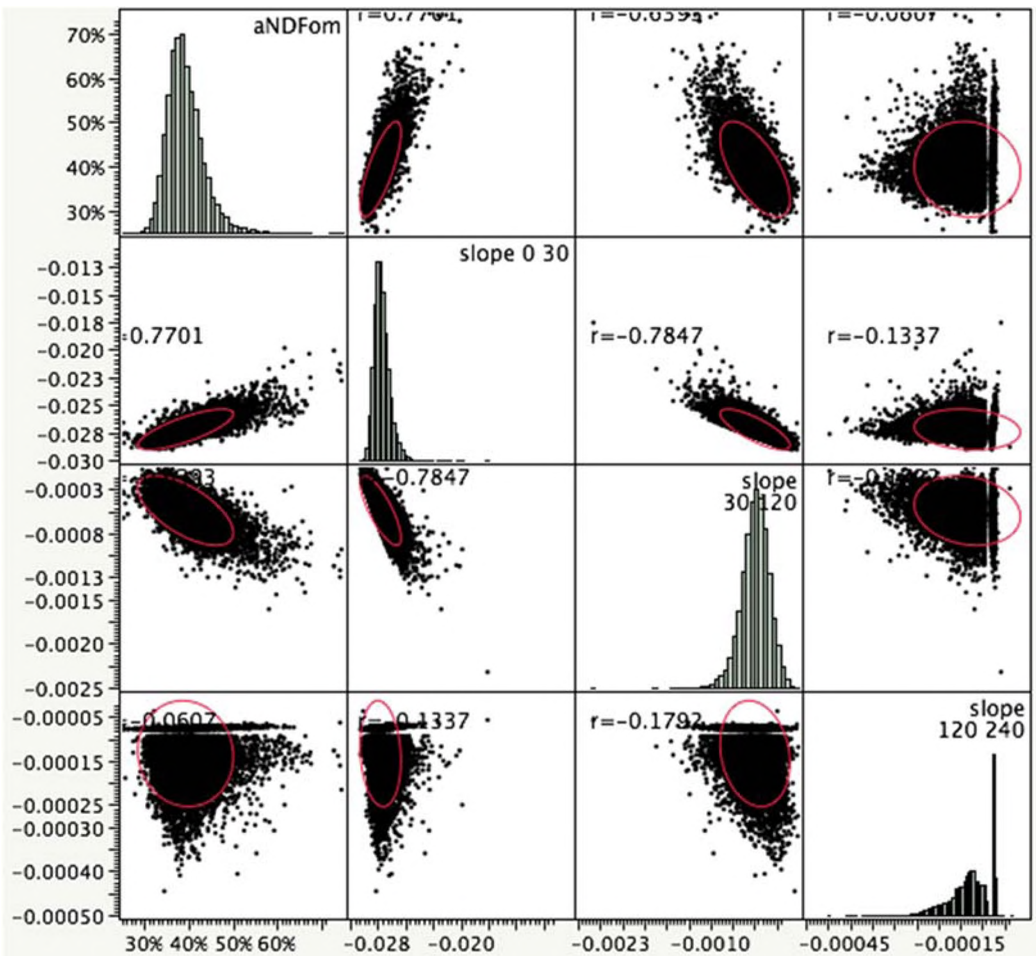

Figure 9. Correlation matrix for aNDFom, 0-30 hr slope, 30-120 hr slope, and 120-240 hr slopes of uNDF for corn silage.

CONCLUSIONS

Fiber is complex. As equipment increases in size, weather leading to greater extremes, and the still large proportion of acreage under flood irrigation, soil contamination in aNDF will be an increasing problem. Migrating to aNDFom addresses this issue and ensures adequate dietary NDF while accounting for NFC appropriately is recommended.

The introduction of multi-pool aNDFom fractions is allowing modelers and nutritionists to better understand this complexity. Slow and unavailable aNDFom have a large impact on rumen kinetics including: rumen fill, dry matter intake, and meal patterns. As illustrated in this manuscript, slow and unavailable aNDFom will remain in the rumen for greater then 144 hrs. Additionally, differences in plant species, coupled with differences in maturity, have significant impact on the size of fast, slow, and unavailable aNDFom.

Given the species differences, it is not possible to establish a set benchmark for uNDF %BW or 30 hr dNDF intake. Nutritionists should be wary when changing from alfalfa to grass based diets as particle size and relative size of slow pool aNDFom greatly impact dry matter intake and resulting performance.

When selecting forages, nutritionists should be cognizant of these pools and their relationships. Selection should be focused on forages that are high in fermentable carbohydrates. It is equally important to convince dairy producers to allocate forages based upon aNDFom pools and fermentability. In many cases this will require several silos to be open simultaneously to deliver specific blends to target groups.

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