

FORAGE FIBER DIGESTIBILITY IN RELATION TO DAIRY COW PERFORMANCE

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Forage neutral detergent fiber (NDF) is retained in the rumen longer, and is therefore more filling than other feed components. Rumen fill can limit feed intake, especially for high producing cows and cows fed high forage diets. There is great variation in the filling effects of forage fiber because of differences in digestion characteristics; forage fiber that digests and passes from the rumen quickly is less filling than forage fiber that digests and passes more slowly. The purpose of this article is to explain the effects of variation in forage fiber digestibility on feed intake and milk yield of dairy cows and to give recommendations for using in vitro NDF digestibility (IVNDFD) test results.

FORAGE NDF CAN LIMIT FEED INTAKE

Forage NDF is needed in diets to maximize milk yield, efficiency of feed utilization, and animal health. Forages provide longer particles than other feed ingredients, which are needed to form a rumen mat that entraps smaller particles, thus increasing their digestibility. A sufficient amount of digesta (partially digested feeds and microbes) is needed to stimulate rumen movements and chewing to prevent acidosis; rumen movements are needed to remove acids from the rumen through absorption, and chewing stimulates salivary buffer secretion, neutralizing or buffering the remaining acids. In addition, a large amount of digesta in the rumen provides a steady supply of energy to the cow over time, which helps partition more energy to milk rather than body condition.

While some forage NDF is necessary in diets for the reasons mentioned, forage NDF can also limit feed intake and milk yield. Feed intake by lactating cows is often reduced dramatically by increasing the forage NDF concentration of the diet. Several studies in the literature reported a decrease in dry matter intake (DMI) of ~ 5 to 9 lb/d when diet NDF content was increased from 25 to 35% by substituting forages for concentrates (Allen, 2000). Although most studies reported a significant decrease in DMI as forage NDF increased, the DMI response was variable, depending upon the degree to which intake was limited by ruminal fill. Higher producing cows are limited by fill to the greatest extent, and the filling effect of forage fiber varies depending upon its digestion characteristics.

IVNDFD OF FORAGES VARIES

In vitro NDF digestibility is a *relative* measure of NDF digestibility and is determined in the laboratory by incubating a feed sample that has been dried and ground with rumen microbes in a buffered solution. IVNDFD can provide valuable information related to the intake potential of the forage NDF. Evaluation of forage samples varying in genetics and grown in different environments showed that IVNDFD ranged from less than 30% to over 60% for both alfalfa and whole plant corn samples (Allen and Oba, 1996). This large variation has a great effect on the filling characteristics of the forage NDF over time in the rumen.

ENHANCED FORAGE IVNDFD INCREASES INTAKE, MILK YIELD

Several experiments compared forages with different NDF digestibility, but with similar NDF and CP contents, fed to lactating dairy cows and found significant increases in DMI and milk yield with increased NDF digestibility (Oba and Allen, 1999b). We reported that a one-unit increase in in-vitro or in-situ digestibility of forage NDF was associated with 0.37 lb/day increase in DMI and a 0.55 lb/day increase in 4% fat-corrected milk yield per cow (Oba and Allen, 1999b). We recently reevaluated this relationship for corn silage comparisons reported in the literature since that study. Across 11 corn silage comparisons, a one-unit increase in IVNDFD was associated with 0.26 increase in DMI and a 0.47 lb/day increase in 4% fat-corrected milk yield per cow (Oba and Allen, 2005). This average response across experiments is very similar to the relationship between in vitro NDF digestibility and animal performance that we reported earlier. This average response of ~ 0.5 lb/day of 4% fat-corrected milk per unit of IVNDFD amounts to more than 15 lb/day of 4% fat-corrected milk per cow when the large range in IVNDFD of more than 30 units across forages is considered.

BENEFITS INCREASE AS MILK YIELD OF COWS INCREASES

High yielding cows are challenged to meet their energy requirements, and DMI of these cows is limited by the filling effects of diets to a greater extent than for lower yielding cows consuming the same diet. This is supported by an experiment that compared brown midrib 3 (*bm₃*) corn silage to its isogenic normal corn silage with high yielding dairy cows in a crossover design (Oba and Allen, 1999a). The corn silages had similar contents of DM, NDF, CP, and starch, but the *bm₃* corn silage had 25% greater (9.7 units) in vitro NDF digestibility compared to the control corn silage. Dry matter intake response to the *bm₃* corn silage compared to control was positively related to the milk yield of cows determined before the experiment. Higher producing cows with a milk yield of ~120 lb/d had a response in milk yield of 17 lb/d (with a response in DMI of over 8 lb/d), while lower producing cows with a milk yield of ~70 lb/d had similar feed intake and milk yield for both forages. Therefore, forages with high IVNDFD should be targeted to the highest producing cows in the herd.

Targeting forages with high IVNDFD to high-group cows will result in greater peak milk yield, while forages with low IVNDFD will have less effect on milk yield of lower producing cows because feed intake is less limited by gut fill for these cows. In addition, forages with high IVNDFD will be more beneficial to herds with higher average milk yield per cow than for lower producing herds.

BENEFITS ARE GREATER WHEN COWS ARE FED HIGHER FORAGE NDF DIETS

A greater advantage might be expected for forages with high NDF digestibility when included in high forage NDF diets because gut fill is more of a limitation to DMI as diet forage NDF concentration increases. Enhanced NDF digestibility of *bm*₃ corn silage compared to its isogenic control silage increased DMI and milk yield to a greater extent when fed in higher forage (38% NDF) compared to lower forage (29% NDF) diets (Oba and Allen, 2000).

FORAGES WITH HIGH IVNDFD PARTITION ENERGY TO MILK

The high forage diets in the experiment just mentioned contained only forage (80% corn silage, 20% alfalfa silage), protein supplement, and a mineral and vitamin premix while the low forage diets contained those ingredients as well as ~ 28% supplemental dry corn grain. It is interesting that although DM and energy intake was higher when cows were offered the low forage diet containing the control corn silage compared to the high forage diet containing the *bm*₃ corn silage, milk yield was slightly lower and the cows partitioned more energy to body condition rather than milk. Increasing energy intake with more digestible NDF compared to starch from grain likely partitions more energy towards milk yield. Thus, forages with higher IVNDFD can also be used to prevent excess body condition by feeding higher forage diets without a loss of milk yield.

IVNDFD IS A RELATIVE RANK OF INTAKE POTENTIAL, NOT ENERGY CONTENT

Digestibility of NDF measured in vitro or in situ using a constant incubation time was an important indicator of the filling effects of NDF, but not necessarily an index of energy concentration. Oba and Allen (1999b) reported that differences in NDF digestibility of forages measured in the animal (in vivo) averaged less than 40% of differences measured in vitro or in situ using a constant incubation time. Forages with higher NDF digestibility allowed greater DMI, which probably reduced retention time in the rumen, decreasing differences in NDF digestibility in vivo. In addition, responses in apparent digestibility of DM of *bm*₃ corn silage compared to control corn silage were negatively related to response in DMI (Oba and Allen, 1999a). This is because NDF digestibility of *bm*₃ corn silage compared

with the isogenic control corn silage was depressed as DMI response increased. Although the bm_3 corn silage had 9.7 percentage units higher NDF digestibility in vitro (30-h incubation time) than the isogenic control corn silage, digestibility of NDF measured in vivo ranged from 12 percentage units higher with cows for which DMI of bm_3 corn silage was over 4 lb/d lower than the isogenic control corn silage, to 12 percentage units lower with cows for which DMI of bm_3 corn silage was over 17 lb/d higher than the isogenic control corn silage.

Another experiment in which bm_3 corn silage was compared to its isogenic control corn silage in 29 and 38% NDF diets (Oba and Allen, 2000) provides further support that in vitro NDF digestibility is more specifically related to the filling effects of feed than to in vivo NDF digestibility. Although 30-h in vitro NDF digestibility was 9.4 percentage units greater for the bm_3 corn silage, bm_3 corn silage resulted in greater DMI and rate of passage of NDF at both dietary NDF contents and no differences were observed between the silages for ruminal or whole tract NDF digestibility.

COMPARE IVNDFD WITHIN FORAGE FAMILY ONLY

Dry matter intake of diets containing grass silage by lactating cows is lower than DMI of diets containing alfalfa silage in spite of greater DM and NDF digestibility for grass silage (Weiss and Shockey, 1991; Hoffman et al. 1998). When we evaluated the relationship between forage NDFD and DMI and milk yield we found a different relationship for temperate grasses (orchardgrass, timothy, brome grass, etc.) compared to legumes (primarily alfalfa; Oba and Allen, 1999b). Although NDF digestibilities were often greater for grasses compared to legumes, the filling effect of legumes was less because they are cleared from the rumen faster allowing greater DMI. This is supported by an experiment in which fresh rye-grass decreased in size and was cleared from the rumen of cows more slowly than alfalfa (Waghorn et al., 1989). A recent experiment comparing alfalfa silage (43% NDF, 20% CP) and orchardgrass silage (47% NDF, 20% CP) showed no effect of forage type on feed intake across all cows, but cows with a greater drive to eat responded more positively to alfalfa over grass (Linton and Allen, 2005). Cows with lower DMI before the experiment ate more of the diet containing orchardgrass silage but cows with higher DMI ate more of the diet containing alfalfa silage. Higher producing cows were able to increase passage rate of the alfalfa silage NDF compared to orchardgrass NDF to a greater extent, allowing greater DMI.

Similar DMI observed in comparisons of alfalfa and corn silage (Broderick, 1985; Colenbrander et al., 1986; Dhiman and Satter, 1997; Grant et al., 1995) suggests that the greater filling effects of grass NDF compared to legume NDF is limited to temperate grasses.

SYMPTOMS OF POOR FORAGE NDFD

When a forage with low IVNDFD is substituted in a diet for a forage with higher IVNDFD, DMI and milk yield of the highest producing cows will be limited. This is because gut fill becomes a greater limitation to DMI as milk yield increases and DMI is reduced.

Feed intake of cows with lower milk yield is more likely limited by other factors related to metabolism of absorbed fuels. Milk yield of these cows might not decrease because they are able to increase DMI at least until fill becomes a limitation. Therefore when a group of cows with a wide range of production is fed a forage with lower IVNDFD, DMI might not change for the entire group of cows because it will be lower for high-producing cows, but higher for low-producing cows. However, peak milk yield for individual cows will be lower, milk yield for the group will likely be lower, and the efficiency of converting feed to milk will decrease.

RECOMMENDATIONS

- IVNDFD is a relative rank of intake potential. It should be used to compare forages and for forage allocation rather than to adjust energy concentration of forages.
- IVNDFD can be used to troubleshoot ration problems. Sample the current forage before switching forages. If production decreases, have both forages tested for IVNDFD. Have them tested in the same run because of greater biological variation across runs.
- Select hybrids for IVNDFD. There are repeatable differences in IVNDFD among hybrids for corn and sorghum that are meaningful economically. Difference among alfalfa cultivars are much less.
- Test all forages and allocate those with the highest IVNDFD (except temperate grasses; see below) to the highest producing cows.
- Don't compare IVNDFD across forage families. Temperate grasses are more filling than legumes or tropical grasses (such as corn silage) and allocation to high producing cows should be limited. The relative amount of grass in older stands of alfalfa can be determined by the ratio of acid detergent fiber (ADF) to NDF; ADF represents ~60% of the NDF for grasses but over 80% of the NDF for legumes. Target alfalfa with the highest ADF as a per-cent of NDF and the highest IVNDFD to the highest producing cows.
- When lactating cows are grouped and fed different diets, forages with higher IVNDFD can be used to increase forage NDF concentration in diets of lower producing cows, preventing excessive body condition while maintaining milk yield.

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