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Maximizing Digestible Intake of Corn Silage-based Diets: Part 1

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This is part 1 of a 2-part series that addresses management strategies to formulate diets for carbohydrates for lactating cows that feed on corn silage-based rations. Part 1 focuses on concentration, effectiveness, and digestibility of neutral-detergent fiber (NDF) in corn silage. Part 2 in the October issue of Michigan Dairy Review will focus on ruminal starch digestibility and optimizing fermentability of diets.

Introduction

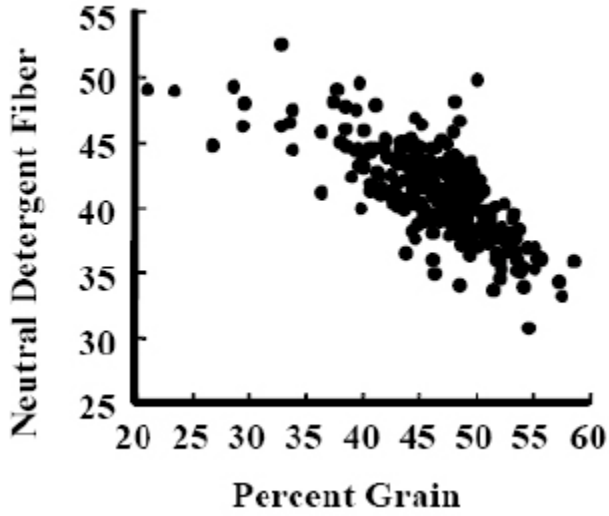
Corn silage is an important source of digestible effective fiber and can be an economical source of energy in diets for lactating cows. However, variation in concentration and digestion characteristics of neutral detergent fiber (NDF) and starch affect supplementation strategies and can affect energy intake and animal performance. One of the most challenging aspects of diet formulation for lactating cows is balancing for carbohydrates.

Adequate effective fiber must be provided to optimize ruminal fermentation. But forage fiber is more filling than other nutritional components of the diet and the filling effect of the diet often limits energy intake of lactating cows. Therefore, diets for lactating cows should be balanced to provide adequate effective fiber with the least filling effect.

A balance must also be attained for ruminal carbohydrate fermentation. Carbohydrate fermentation in the rumen is desirable to provide fuels for microbial growth and production of microbial protein, yet the fermentability of the diet must be limited to prevent excessive production of fermentation acids. Inadequate effective fiber or excessive fermentability of the diet can decrease ruminal pH, feed intake, diet digestibility, and microbial protein production. This is a major problem in many dairy farms that results in poor health, and reduces milk yield and farm profitability. On the other hand, diets with excessive effective fiber that are more filling and diets that are poorly fermentable also can result in lower milk yield and profitability because of reduced energy intake and microbial yield.

Both situations can be thought of as lost opportunity for maximization of farm profits. Corn silage contains about 70% carbohydrate from NDF and starch. The digestibility of the NDF and starch in corn silage is highly variable depending upon genetics, as well as environmental and management factors. Variation in concentration and digestibility of NDF and starch of corn silage provides challenges to maximize energy intake and production.

Figure 1. Relationship between percent grain in corn silage and concentration of neutral detergent fiber (% of DM) for corn silage grown in Michigan in 1988 and 1989.



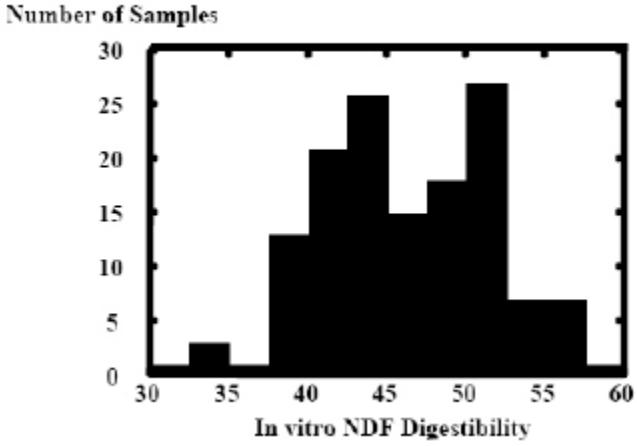
Concentration of NDF and Starch

The primary carbohydrates in corn silage are starch and the NDF carbohydrates, cellulose and hemicellulose. Grain concentration of corn silage dilutes the NDF fraction, which ranges from <35% to more than 50% (Figure 1). Because of this, starch concentration is also inversely related to NDF concentration and ranges from less than 5% to more than 40% of corn silage DM.

The primary factors affecting concentrations of NDF and starch in corn silage are plant genetics and maturity at harvest (Allen et al., 2003). Corn hybrids range from less than 38% to over 52% NDF. Other, minor factors affecting corn silage NDF and starch concentrations include environment, population density, harvest height, and fertilization (Allen et al., 2003).

Grain is more digestible than stover so digestibility of corn silage is positively related to its grain concentration. However, grain concentration, as well as concentrations of NDF and starch of corn silage, is not necessarily related to energy intake or animal performance because diets are usually formulated to specific NDF and starch concentrations using supplemental grain. The starch concentration of dairy cattle diets is inversely related to the NDF concentration and concentrations of both are typically in the range of ~ 26 to 32% of dietary DM for lactating cows.

Figure 2. Variation in digestibility of neutral detergent fiber (NDF) of corn forage samples (32 hybrids grown in four locations in Michigan in 1988 and 1989).



Low grain corn silages with low starch and high NDF concentrations are typically included in the diet at lower concentrations and supplemented with more corn grain to achieve the same dietary NDF and starch concentration. The effect on diet cost is dependent on the relative cost of corn grain compared with corn silage and is farm and time dependent.

Effectiveness of NDF

Long fiber particles (effective fiber, mostly from forage) are needed in the diet to maximize production at least four different ways:
1) stimulation of rumen motility, which increases VFA absorption;
2) stimulation of chewing which results in the secretion of salivary buffers;
3) formation of a rumen mat that entraps small particles, increasing their ruminal digestibility; and,
4) provides a consistent source of fuels to the microbes in the rumen which functions to provide a steady supply of fuels to the liver and mammary gland over time.

Effectiveness of fiber in corn silage is dependent upon the theoretical length of cut (TLC) set on the chopper, and further particle reduction if processed, ensiled in bags (from the auger), and during mixing. Furthermore, variation in particle size of TMRs allows selection by cows during eating, particularly for dry rations. Low-lignin corn silages with highly fermentable fiber might be less effective at stimulating chewing than less-fermentable fiber sources (Taylor and Allen, 2005).

Finely chopped corn silage (e.g. 3/8-inch TLC) is less likely to be sorted but requires other forage with longer particles to provide adequate effective NDF in the diet. Coarsely chopped corn silage (e.g. >3/4-inch TLC) will increase the effectiveness of NDF from corn silage but will also allow sorting by cows. Optimum particle size of corn silage is dependent upon many factors including the fermentability of the diet, and the effectiveness of other forages in the diet.

NDF Digestibility

Corn silage NDF digestibility measured in vitro is extremely variable. Allen (1993) reported that in vitro NDF digestibility (IVNDFD) of whole plant corn forage ranged from approximately 60% for 32 corn hybrids grown in four locations in Michigan in 1988 and 1989 (Figure 2). This

variation was primarily from differences in growing environment between years and locations and in hybrid genetics.

Management factors such as population density, soil fertility, planting date, and harvest moisture were relatively constant among plots but, if allowed to vary, would increase variation further. Although the growing environment is the greatest factor affecting NDF digestibility of corn silage, there are consistent hybrid effects (Allen et al, 2003).

Typical commercial corn hybrids vary by 4 to 5 percentage units of NDF digestibility while the brown midrib mutants increase this variation by another 4 to 5%.

Other factors have somewhat less effect on NDF digestibility; in vitro NDF digestibility decreased by about 4 percentage units as forage dry matter increased from 30% to 41% and increased <1.5 percentage units as plant population increased from 18,000 to 34,000 plants per acre (Allen, 1992).

These relatively small differences in in vitro NDF digestibility can have large effects on animal performance. Oba and Allen (1999a) reported that enhanced forage NDF digestibility increased dry matter intake DMI and milk yield of dairy cows across a wide range of forages reported in the literature.

A one-unit increase in NDF digestibility in vitro or in situ was associated with a 0.37-lb increase in DMI of diets and a 0.55 lb increase in 4% fat-corrected milk. However, increased IVNDFD does not always result in increased feed intake.

Response in intake to forages with increased IVNDF digestibility is dependent upon both animal and dietary factors; response is greatest for animals with high energy requirements and diets lower in energy (Allen, 2000).

Oba and Allen (1999b) compared production responses of 32 cows with high milk yield (100 lbs per day) fed a low lignin brown midrib-3 corn silage compared with its isogenic normal control corn silage in diets containing 45% corn silage, 11% alfalfa silage, and energy and protein concentrates in a crossover experiment.

In vitro NDF digestibility (30-hr incubation) of the low-lignin corn silage was 9.7 percentage units higher than the control silage. Dry matter intake and 3.5% FCM yield were increased by 4.6 and 5.7 lb per day, respectively, when the corn silage with higher IVNDFD was fed.

Dry matter intake and milk yield responses for the low-lignin corn silage were linearly and positively related with pre-trial milk yield suggesting that DMI of greater producing cows was limited by physical fill to the greatest extent.

It is important to note that although the low lignin brown midrib-3 corn silage had 9.7 units greater in vitro NDF digestibility than the normal corn silage, the difference in NDF digestibility in vivo ranged from about 15 units lower to about 15 units higher for the brown midrib-3 corn silage.

Furthermore, the response in NDF digestibility in vivo was linearly and negatively related to response in DMI. Therefore, NDF digestibility measured in vitro or in situ is not a reliable indicator of energy concentration but it is related to dry matter intake.

In vitro digestibility of corn silage NDF was not related to concentration of NDF and was not highly related to concentration of acid detergent fiber (ADF) in the whole plant for 32 corn hybrids grown in several locations in Michigan in 1988 and 1989 (Allen et al., 2003).

However, acid detergent sulfuric acid lignin as a fraction of NDF was highly related to IVNDFD for the same corn forage samples (Allen et al., 2003). Because lignin is more easily and economically measured than IVNDFD, it might be a useful index of ease of NDF breakdown for use in the field.

References available upon request to the author at: allenm@msu.edu.