Defining Effective Fiber and Fiber Recommendations for Dairy Cows

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Introduction

Current NRC recommendations for dairy cattle provide only minimum recommendations for chemically measured fiber. However, physical characteristics of fiber can influence animal health, ruminal fermentation, animal metabolism, and milk fat production independently of the amount of chemically measured fiber. Using ground fibrous by-product feeds or finely chopped forages in rations that contain adequate amounts of fiber often results in reduced animal performance. This indicates that the effectiveness of fiber in maintaining animal health and productivity varies with its physical form.

Fiber recommendations for dairy rations can be improved by adjusting fiber for its effectiveness in maintaining chewing activity, ruminal pH, and milk fat percentage. Being a nutritional concept, it is clear that fiber effectiveness can be measured only by the animal. Although neutral detergent fiber (NDF) is a useful measurement of total fiber in feeds, it does not measure the physical characteristics of fiber related to effectiveness. The objective of this research was to (1) define physically effective NDF (peNDF), (2) derive coefficients for estimating peNDF, and (3) develop preliminary estimates of peNDF recommendations for dairy cows.

Materials and Methods

To develop the relationships among NDF, physical form of the NDF, and chewing activities of dairy cows consuming concentrates and fibrous by-product feeds, 39 experiments in which chewing activities were measured (214 cow-treatment combinations) were compiled from the literature. A system for classifying the physical form of feeds was designed based on the quantitative particle size information provided by various authors (Table 1). Feeds were assigned to a class based on the description of the feeds provided by the authors. If no particle size information was provided, feeds were assigned to the median class for that feed source.

Estimates of peNDF requirements for maintaining milk fat were made using a database containing 112 cow-treatment combinations from 26 experiments. A database containing 88 cow-treatment observations from 20 experiments was used to determine the peNDF requirement for maintaining ruminal pH. Experiments were restricted to those in which ruminal pH was measured a minimum of five times over an 8h period after feeding. To remove variation associated with experimental location, all regression models for determining requirements included a class variable for the institute at which the experiment was conducted.

Results and Discussion

Physical effectiveness of NDF was defined as the fraction of NDF that influences chewing activity and the biphasic nature of rumen contents (floating mat of large particles on a pool of small particles and liquid). Factors that are related to particle size and particle size reduction and their impact on optimal fermentation should be related to peNDF. Thus, peNDF is related to ruminal pH regulation via the production of salivary buffers during eating and rumination. It is also related to the formation of the mat in the rumen, which may be a critical component of the selective retention of fiber for digestion in the rumen and for the stimulation of rumination.

Long grass hay was observed to have the largest eating, ruminating, and total chewing activity per kg of NDF intake; therefore, it was used as the standard for calculating the physical effectiveness factors for all other NDF sources (Table 2). Physically effective NDF predicted total chewing activity with an R^2 of .66. Although this R^2 may seem low, the data base: (1) included 15 data sets that appeared to be outliers, (2) used some estimates of NDF and physical form classification, (3) contained observations on lactating and nonlactating cows, restricted and ad libitum feeding, and separate and total mixed rations, and (4) made comparisons across experiments; therefore, variation associated with measurement techniques, feeding systems, facilities, and animals is included in the overall R^2.

The product of observed NDF and the physical effectiveness factors in Table 2 estimates peNDF of a feed. Regression of peNDF (% of ration DM) versus milk fat percentage or ruminal pH was used to estimate recommendations. These equations indicate that 24.1 and 18.7% peNDF in ration DM would maintain milk fat concentration at 3.5 and 3.3%, respectively. Ruminal pH may be a better indication of ruminal health and optimal function than the maintenance of milk fat production because factors other than physical effectiveness of fiber influences milk fat synthesis. Solutions of the regression equations for maintaining an average pH of 6.2, 6.1 and 6.0 using ground corn as the concentrate source were 30.3, 26.7, and 22.1% peNDF in ration DM. Based on these results, the minimum recommendations for peNDF of dairy cows is between 19% (to maintain the milk fat percentage of early to mid lactating cows at 3.3%) and 22% of ration DM (to maintain an average ruminal pH of 6.0).

Conclusions

Fiber is an important characteristic of feeds that can be used to formulate optimal rations. Adjusting fiber for effectiveness provides a means of fine-tuning the formulation of dairy rations. A system is proposed that is based on NDF as the measure of total chemical fiber in feeds. Adjustments for effectiveness of NDF in maintaining milk fat production and optimizing ruminal fermentation are based on the particle size and inherent characteristics of NDF that affect chewing activity. The system can provide practical guidelines for improving current fiber recommendations and serve as a framework for future research on meeting the fiber requirements of dairy cows.

Table 1. Physical form classification system used to describe feeds in published experiments.

Description	TLC[a]	Screen Size[b]	Grass hay	Grass silage	Corn silage	Alfalfa hay	Alfalfa silage	Concentrates
Long			Long					
Coarse chopped	4.8 to 8.0		Coarse	Long		Long		
Medium-coarse chopped	2.4 to 4.0		Medium	Medium	Long	Coarse		
Medium chopped	1.2 to 2.0		Short	Short	Medium	Medium	Long	
Medium-fine chopped	.6 to 1.0				Short	Short	Medium	
Fine chopped	.3 to .5						Short	
Ground or pelleted	.15 to .25		Ground			Ground		
			Pelleted			Pelleted		
Rolled								B, HMC[c]
Coarse ground or cracked		1.25						Cr. Corn[d]
Medium ground		.90						C, Complex[e]
Fine ground or pelleted		.63						Pelleted

[a]Theoretical length of cut in cm.

[b]Grinder screen aperture in cm.

[c]Barley and high moisture corn (both shelled and ear corn).

[d]Cracked corn.

[e]Ground corn and complex mixtures of fibrous protein supplements and nonforage fiber sources.

Table 2. Physical effectiveness factors for NDF in feeds of each physical form classification for eating, ruminating, and total chewing time relative to long grass hay.

Description	TLC[a]	Screen Size[b]	Eating factor[c]	Ruminating factor[d]	Total chewing factor[e]
Long			1.00	1.00	1.00
Coarse chopped	4.8 to 8.0		.95	.95	.95
Medium-coarse chopped	2.4 to 4.0		.90	.90	.90
Medium chopped	1.2 to 2.0		.85	.85	.85
Medium-fine chopped	.6 to 1.0		.85	.80	.80
Fine chopped	.3 to .5		.80	.65	.70
Ground or pelleted	.15 to .25		.40	.15	.25
Rolled			.80	.50	.60
Coarse ground or cracked		1.25	.60	.30	.40
Medium ground		.90	.50	.20	.30
Fine ground or pelleted		.63	.40	.15	.25

[a]Theoretical length of cut in cm.
[b]Grinder screen aperture in cm.
[c]Eating time (min/kg of NDF) equals the corresponding coefficient times 60.
[d]Ruminating time (min/kg of NDF) equals the corresponding coefficient times 110 - .8(FCM).
[e]Total chewing time (min/kg of NDF) equals the corresponding coefficient times 170 - .8(FCM).