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# Altering Physically Effective Fiber Intake Through Forage Proportion and Particle Length: Digestion and Milk Production[1]

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## ABSTRACT

Intake of physically effective neutral detergent fiber (peNDF) of dairy cows was altered by adjusting the proportion of forage in the diet and forage particle length, and effects on nutrient intake, site and extent of digestion, microbial N synthesis, and milk production were measured. The experiment was designed as a triplicated 4 × 4 Latin square using 12 lactating dairy cows, with 4 that were ruminally and duodenally cannulated, 4 that were ruminally cannulated, and 4 that were intact. Thus, the site and extent of digestion, and microbial N synthesis were measured in a single 4 × 4 Latin square. Treatments were arranged in a 2 × 2 factorial design; 2 forage particle lengths (FPL) of alfalfa silage (short and long) were combined with low (35:65) and high (60:40) forage:concentrate (F:C) ratios (dry matter basis). Dietary peNDF content was determined from the sum of the proportion (dry matter basis) of dietary dry matter retained either on the 2 screens (8- and 19-mm) or on the 3 screens (1.18-, 8-, and 19-mm) of the Penn State Particle Separator multiplied by the neutral detergent fiber content of the diet. An increased F:C ratio reduced intakes of dry matter and starch by 9 and 46%, respectively, but increased intake of fiber from forage sources by 53%. Digestibility of dry matter in the total tract was not affected, whereas total digestion of fiber and N was improved by increasing the F:C ratio. Improved total fiber digestion resulted from higher ruminal digestion, which was partially due to a shift in starch digestion from the rumen to the intestine with the increased F:C ratio. Actual milk yield was decreased but production of 4% fat-corrected milk was similar between the low and high F:C diets because of increased milk fat content. Increased FPL increased intake of peNDF, especially when the high F:C diet was fed. However, nutrient intakes, N metabolism in the digestive tract, and milk production were not affected. Digestibility of neutral detergent fiber in the total tract was increased because of improved fiber digestion in the rumen with increased FPL. These results indicate that feeding dairy cows a low F:C diet is beneficial in terms of increasing feed intake, microbial N synthesis, and milk production. However, low F:C diets do not maximize feed digestion and production efficiency because of the effects of subacute ruminal acidosis. Increased FPL improves fiber utilization with minimal effects on the digestion of other nutrients and milk production. Increasing dietary peNDF, through an increased proportion of forage or increased FPL, improves fiber digestion because of improved rumen function.
**Key words:** physically effective neutral detergent fiber, digestion, microbial nitrogen synthesis, dairy cow

## INTRODUCTION

The rumen environment and associated microbial populations are designed to function optimally within a pH range of 6.2 to 7.2. However, this range of pH is rarely observed in high-producing dairy cows because their diets are high in concentrate and low in fiber to encourage maximum milk production. Suboptimal ruminal pH (e.g., pH 5.2 to 5.8) is referred to as subacute ruminal acidosis (**SARA**; Owens et al., 1998). The incidence of SARA is a tremendous problem for the dairy industry in terms of lost production efficiency and increased cost of treating sick animals (Nocek, 1997). Subacute ruminal acidosis reduces microbial activity, fiber digestion, and the microbial AA supply.

The concept of physically effective NDF (**peNDF**) is a means of formulating diets to provide fiber of adequate particle length to reduce SARA. Physically effective NDF reflects the ability of the feed to promote chewing and the salivary secretions needed to buffer the rumen and elevate ruminal pH (Mertens, 1997). A number of studies have recently shown that increased intake of peNDF increases chewing activity and ruminal pH (Krause et al., 2002b; Beauchemin et al., 2003), improves total digestibility (Kononoff and Heinrichs, 2003a; Yansari et al., 2004; Yang and Beauchemin, 2005), and increases milk fat content (Yang et al., 2001; Kononoff and Heinrichs, 2003a). However, other stud-

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ies have demonstrated either no effects or negative effects of peNDF on ruminal pH (Fernandez et al., 2004; Beauchemin and Yang, 2005), digestibility, and milk composition (Krause et al., 2002a; Kononoff and Heinrichs, 2003b). Beauchemin and Yang (2005) concluded that the variable effects of dietary peNDF content on rumen function, digestion, and productivity of dairy cows are because peNDF content of diets can be increased by increasing the forage proportion of the diet or by increasing the particle length of forages. An increased forage proportion would affect intake of fermentable OM as well as intake of fiber, which could have a significant impact on peNDF requirements. Little information is available documenting the influence of ruminally fermentable carbohydrates on the effects of dietary peNDF levels.

The objectives of the present study were to determine the effects of, and interactions between, level of ruminally fermentable carbohydrate and dietary peNDF content on feed intake, site and extent of digestion, microbial N synthesis, and milk yield and composition of lactating dairy cows. Dietary peNDF content was varied by adjusting the proportion of forage in the diet and the particle length of silage. Adjusting the proportion of forage in the diet also varied the intake of ruminally fermentable carbohydrate. The effects on chewing activity, ruminal pH, and fermentation were also measured but will be reported separately.

## MATERIALS AND METHODS

### *Alfalfa Silage*

Second-cut, wilted alfalfa silage (**AS**) was harvested at the early bloom stage of maturity and ensiled in large silo bags (200-tonne capacity) for 2 mo before being used. A forage harvester (model 6910, John Deere, West Bend, WI), equipped with a 37-tooth sprocket and 8 knives, was used to obtain silage chopped at a theoretical chop length (**TCL**) of 7.9 and 19.1 mm for short and long cut silage, respectively. Two kilograms of each AS (short and long) were obtained weekly and immediately subdivided into 3 portions to determine DM content, particle size, and chemical composition, respectively (Table 1). Particle size distribution of the silage was determined using the Penn State Particle Separator (**PSPS**; Kononoff and Heinrichs, 2003b) equipped with 3 sieves (19, 8, and 1.18 mm) and a pan. Dry matter content was determined by oven-drying at 55°C for 48 h. The third portion of the samples was composited by experimental period and retained for determination of chemical composition. Fermentation characteristics of the silage were determined commercially by Cumberland Valley Analytical Service Inc. (Maugansville, MD) from one single representative sample from the silo before starting the experiment.

### *Cows and Diets*

Twelve lactating dairy cows were used, including 4 that were ruminally and duodenally cannulated, 4 that were ruminally cannulated, and 4 that were intact. The experiment was designed as a triplicated 4 × 4 Latin square with a 2 × 2 factorial arrangement of treatments for measuring intake, total digestibility, milk yield, and milk composition. However, site of digestion and ruminal microbial production were measured with a single 4 × 4 Latin square. The ruminal cannulas measured 10 cm in diameter and were constructed of soft plastic (Bar Diamond, Parma, ID). Duodenal cannulas were T-shaped and were placed proximal to the common bile and pancreatic duct, approximately 10 cm distal to the pylorus. Cows were housed in individual tie stalls and offered a TMR 3 times daily at 0600, 1500, and 1800 h for ad libitum intake. Cows averaged 622 ± 65 kg of BW and 63 ± 13 DIM and were cared for according to the Canadian Council on Animal Care Guidelines (Ottawa, Ontario, Canada).

Cows were offered 1 of 4 diets consisting of the short and long AS, combined with low (35:65) and high (60:40) forage:concentrate (**F:C**) ratios (DM basis; Table 2). Thus, intake of peNDF was increased by increasing forage particle length (**FPL**) and proportion of forage in the diet. Contents of peNDF ranged from 9.6 to 19.8% or from 28.6 to 34.0% for peNDF estimated with 2 sieves (Lammers et al., 1996) or with 3 sieves (Kononoff et al., 2003), respectively (Table 3). The diets were formulated using the NRC (2001) model to supply sufficient energy and N for a 650-kg cow to produce 35 kg/d of milk containing 3.5% fat and 3.2% protein.

Each period consisted of 11 d of adaptation to diets and 10 d of experimental measurements. Feed offered and orts were measured and recorded daily during the last 10 d of the period to calculate feed intake. Feed samples including the AS and TMR were collected once weekly, and orts were collected daily and composited weekly for particle length and DM determination. Samples were then composited by period, dried in an oven at 55°C for 48 h, and ground through a 1-mm diameter screen (standard model 4, Arthur H. Thomas Co., Philadelphia, PA) for analysis of OM, NDF, ADF, starch, and CP. Milk production was recorded daily, a.m. and p.m., and was sampled on 5 consecutive days during the last 10 d of the period for milk fat, CP, and lactose determination using an infrared analyzer (MilkOScan 605, Foss Electric, Hillerød, Denmark).