J. Dairy Sci. 89:217–228

Effects of Physically Effective Fiber on Chewing Activity and Ruminal pH of Dairy Cows Fed Diets Based on Barley Silage[1]

W. Z. Yang and K. A. Beauchemin[2]
Agriculture and Agri-Food Canada, Research Centre, Lethbridge, AB, Canada T1J 4B1

ABSTRACT

The objective of this study was to investigate the effects of physically effective neutral detergent fiber (peNDF) content of dairy cow diets containing barley silage as the sole forage source on feed intake, chewing activity, and ruminal pH. The experiment was designed as a replicated 3 × 3 Latin square using 6 lactating dairy cows with ruminal cannulas. Cows were offered 1 of 3 diets (high, medium, and low peNDF) obtained using barley silage that varied in particle length: long (theoretical cut length of 9.5 mm), medium (equal proportions of long and fine silages), and fine (theoretical cut length of 4.8 mm). The peNDF contents were determined using the Penn State Particle Separator and were 13.8, 11.8, and 10.5%, for the high, medium, and low diets, respectively. The physical effectiveness factors (defined as proportion retained on 19- and 8-mm screens) for the long and fine silages were 0.84 and 0.68, respectively. Increased forage particle size increased intake of peNDF but did not affect intake of DM and NDF. Ruminating and total chewing time were linearly increased with increasing dietary peNDF. Mean ruminal pH, area between the curve and a horizontal line drawn at pH 5.8 or 5.5, and time that pH was below 5.8 or 5.5 were not affected by peNDF content. Intake of peNDF was not correlated to any chewing activity but proportion of long particles on the 19-mm sieve tended to be correlated to ruminating chews (r = 0.36) and ruminating time (r = 0.36). These results indicate that increasing the peNDF content of diets increases chewing time. However, increased chewing time does not always improve ruminal pH status. Increasing chewing time and thus increasing salivary secretion may not fully overcome the effects of feed digestion and the production of fermentation acids that lower rumen pH. The results suggest that dietary peNDF and fermentable OM intake are critical in regulating rumen pH. Dietary particle size, expressed as peNDF, was a reliable indication of chewing activity.

Key words: physically effective neutral detergent fiber, chewing, rumen pH, dairy cow

INTRODUCTION

Subacute ruminal acidosis (**SARA**) is a common and economically important metabolic disorder in dairy cattle (Nocek, 1997). Ruminal acidosis occurs when the pH in the rumen declines below optimum for fiber digestion by the rumen bacteria (Beauchemin, 2000). Low ruminal pH is the result of an accumulation of VFA due to feeding diets containing high proportions of fermentable concentrate and forage with low physically effective fiber (**peNDF**). Although these types of diets maximize milk production, they also increase the incidence of SARA. Subacute acidosis can reduce fiber digestion and cause inconsistent feed intake, diarrhea, low milk fat, laminitis, and other health disorders (Nocek, 1997). The economical losses from SARA are attributed not only to health problems, but also to increased feed costs due to poor fiber digestion and lower feed efficiency.

Fermentation acids in the rumen are mainly removed either by absorption through the ruminal wall or through neutralization by salivary and other buffers. It is estimated that salivary buffers account for about 30 to 40% of the neutralization of fermentation acids in the rumen (Allen, 1997). Salivary secretion increases when dairy cows chew during eating and ruminating time (Maekawa et al., 2002). Hence, it is usually assumed that increasing chewing time through manipulating dietary particle size improves ruminal pH status and thus potentially reduces the risk of ruminal acidosis (Yang et al., 2001; Krause et al., 2002).

A number of systems that predict the amount of chewing of various feeds or the effectiveness of feeds to maintain milk fat content have been proposed for use in dairy ration formulation. Of the proposed fiber systems, the concept of peNDF proposed by Mertens (1997) is most closely related to ruminal pH because it is a measure that reflects the physical characteristics of fiber, mainly particle size, and its ability to stimulate chewing and saliva buffering in the rumen. The peNDF of a feed is the product of its physical effectiveness factor (**pef**) and NDF concentration. However, the NRC (2001) pro-

Received May 16, 2005.
Accepted August 30, 2005.
[1]Contribution number (387) 05032.
[2]Corresponding author: beauchemin@agr.gc.ca

vides no recommendations for inclusion of peNDF because of the lack of a standard, validated technique to quantify the physically effective properties of fiber in a diet. Although a number of studies have been conducted in recent years to determine the effects of dietary peNDF on feed intake, chewing time, and ruminal pH (Yang et al., 2001; Krause et al., 2002; Beauchemin et al., 2003; Kononoff et al., 2003; Plaizier, 2004), most have been conducted using corn grain-based diets. Barley grain contains more NDF than corn grain, and barley starch is more rapidly fermentable than corn starch (Yang et al., 1997). The requirements of dietary particle size by dairy cows fed barley grain-based diets can be different from those of cows fed corn grain-based diets. In addition, the Penn State Particle Separator (**PSPS**) is a quick and cost-effective method to estimate forage and TMR particle size and was constructed for particle size determination of feeds on-farm (Lammers et al., 1996). Although the apparatus has been widely accepted, few studies have attempted to investigate effects of forage particle size measured by the PSPS for barley grain based-diets. The objectives of the present study were to determine the effect of particle size of barley silage (**BS**) when fed in combination with barley grain on feed intake, chewing activity, ruminal pH, and fermentation in lactating dairy cows. The recent addition of a 1.18-mm screen to the PSPS results in the retention of almost the entire sample for haylages and corn silages (Kononoff and Heinrichs, 2003a), and thus, overestimates the proportion of particles >1.18 mm. Hence, the original PSPS was used to measure particle size distribution of the BS and TMR. The effects on site and extent of digestion, microbial protein synthesis, and milk yield, and composition of lactating dairy cows were measured and reported separately (W. Z. Yang and K. A. Beauchemin, unpublished data).

MATERIALS AND METHODS

Barley Silage

Whole plant barley (Westford, 6-row hooded hay barley, Bozeman, MT) was harvested at a moisture content of 65% from one field and ensiled on the same day in a large silo bag (200 tonne capacity) 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 cut length (**TCL**) of 9.5 and 4.8 mm for long and short cut, respectively. Two kilograms of each BS (long and short) were obtained weekly and immediately subdivided into 3 portions for determining particle size, DM content, and chemical composition, respectively (Table 1). Particle size distribution of the silage was determined using the PSPS (Lammers et al., 1996) containing 2 sieves (19 and 8 mm) and a pan. The DM content was determined by oven drying at 55°C for 48 h. The third portion of each sample was composited by experimental period and retained for determination of chemical composition. Fermentation parameters of the silage as sampled from the silo midway through the experiment were determined commercially by Cumberland Valley Analytical Service, Inc. (Maugansville, MD).

Table 1. Chemical composition and particle size distribution of barley silage measured using the Penn State Particle Separator

Item	Barley silage		SE	Effect $P <$
	Long cut	Short cut		
Chemical composition				
DM, %	39.8	37.9	1.3	0.05
OM, % DM	88.1	89.8	1.0	NS
NDF, % DM	43.2	42.6	0.5	0.05
ADF, % DM	24.3	23.7	0.7	NS
Starch, % DM	21.6	21.9	0.8	NS
N, % DM	2.35	2.30	0.03	0.10
Physical determination[1]				
% DM retained on sieves				
19.0 mm	4.1	1.5	0.1	0.01
8.0 mm	80.0	66.9	1.6	0.01
Pan	15.9	31.6	1.6	0.01
pef	0.84	0.68	0.02	0.01
peNDF, %	36.4	29.1	1.2	0.01
Fermentation[2]				
pH	3.91	3.92	—	—
Acetic acid, % DM	1.12	1.03	—	—
Propionic acid, % DM	<0.01	<0.01	—	—
Butyric acid, % DM	<0.01	<0.01	—	—
Lactic acid				
% DM	7.3	6.0	—	—
% total acid	86.7	85.4	—	—
Ammonia, % DM	0.6	0.6	—	—

[1]Particle size distribution of barley silage was measured using Penn State Particle Separator (Lammers et al., 1996); the physical effectiveness factor (pef) was determined as the proportion of particles retained by both sieves; and peNDF (physically effective NDF) was measured as the NDF content of the silage multiplied by the pef.

[2]Fermentation parameters were determined by Cumberland Valley Analytical Service, Inc. (Maugansville, MD) using a single representative sample.

Cows and Diets

Six lactating Holstein cows were used in an experiment to investigate effects of peNDF content of BS-based diets on feed intake, eating patterns, diurnal variation of chewing activity, ruminal pH, and characteristics of ruminal fermentation. The cows were fitted with ruminal cannulas, and averaged 652 ± 118 kg of BW and 189 ± 39 DIM at the start of the experiment. Cows were randomly assigned to a replicated 3 × 3 Latin square with 2 different squares for balancing carryover