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Effect of reducing dietary forage in lower starch diets on performance, ruminal characteristics, and nutrient digestibility in lactating Holstein cows

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ABSTRACT

This experiment evaluated the effect of feeding a lower starch diet (21% of dry matter) with different amounts of forage (52, 47, 43, and 39% of dry matter) on lactational performance, chewing activity, ruminal fermentation and turnover, microbial N yield, and total-tract nutrient digestibility. Dietary forage consisted of a mixture of corn and haycrop silages, and as dietary forage content was reduced, chopped wheat straw (0–10% of dry matter) was added in an effort to maintain chewing activity. Dietary concentrate was adjusted (corn meal, nonforage fiber sources, and protein sources) to maintain similar amounts of starch and other carbohydrate and protein fractions among the diets. Sixteen lactating Holstein cows were used in replicated 4 × 4 Latin squares with 21-d periods. Dry matter intake increased while physically effective neutral detergent fiber ($peNDF_{1.18}$) intake was reduced as forage content decreased from 52 to 39%. However, reducing dietary forage did not influence milk yield or composition, although we observed changes in dry matter intake. Time spent chewing, eating, and ruminating (expressed as minutes per day or as minutes per kilogram of NDF intake) were not affected by reducing dietary forage. However, addition of chopped wheat straw to the diets resulted in greater time spent chewing and eating per kilogram of $peNDF_{1.18}$ consumed. Reducing dietary forage from 52 to 39% did not affect ruminal pH, ruminal digesta volume and mass, ruminal pool size of NDF or starch, ruminal digesta mat consistency, or microbial N yield. Ruminal acetate-to-propionate ratio was reduced, ruminal turnover rates of NDF and starch were greater, and total-tract digestibility of fiber diminished as dietary forage content decreased. Reducing the dietary forage content from 52 to 39% of dry matter, while increasing wheat straw inclusion to maintain chewing and rumen function, resulted in similar milk yield and composition although feed intake increased. With the lower starch diets in this short-term study, the minimal forage content to maintain lactational performance was between 39 and 43%.

Key words: low starch diet, low forage diet, rumen dynamics, digestibility

INTRODUCTION

Increased ethanol production in the United States and the resulting higher price for corn has led to replacement of corn grain by non-forage fiber sources (**NFFS**) resulting in lower starch diets for lactating dairy cows (Dann et al., 2008; Bradford and Mullins, 2012). Lower starch diets (20–23% of DM) generally do not adversely affect lactational performance or ruminal fermentation compared with higher starch diets (>25% of DM; e.g., Gencoglu et al., 2010), but the combination of feeding lower starch and lower forage diets is relatively unexplored. Although dairy cows and rumen microbes do not have a specific requirement for starch, it is important to provide adequate total fermentable carbohydrates in the diet. Previous research supports replacement of the rapidly fermentable carbohydrates provided by corn grain with digestible carbohydrates from NFFS with the expectation of little alteration in milk production (Voelker and Allen, 2003; Dann et al. 2008; Gencoglu et al., 2010).

Ruminal pH is lower when the forage-to-concentrate ratio is decreased (Yang and Beauchemin, 2007, 2009). Moreover, reductions in ruminal pH below ~5.8 for greater than 5.24 h/d, especially when combined with high milk production, may result in subacute ruminal acidosis, leading to compromised efficiency of microbial fermentation, fiber digestion, and nutrient utilization (Yang and Beauchemin, 2007; Plaizier et al., 2008; Zebeli et al., 2008). Providing sufficient physically effective NDF (**$peNDF_{1.18}$**), defined as the particle size of the fiber >1.18 mm, supports normal ruminal function due to longer forage particles enhancing chewing

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during eating and ruminating, salivary buffer secretion reducing acid production, and ruminal digesta mat formation (Mertens, 1997).

Feeding higher forage diets results in greater peNDF in the diet, but high-producing cows may be physically unable to consume enough of a higher forage diet to optimize milk production due to limited gut capacity (Allen, 2000). Additionally, poor forage growing and harvesting conditions may result in limited availability of forage. Nonforage fiber sources can partially replace forage fiber, resulting in increased ration nutrient density while allowing for adequate DMI (Kononoff et al., 2006; Zebeli et al., 2012), but these NFFS do not promote chewing activity due to their small particle size and high digestibility.

Mertens (1997) reported that not all forage NDF sources, at the same particle size, stimulate chewing activity equally. For example, oat straw stimulated more chewing per kilogram of NDF than did legume or grass hays. Based on this difference in chewing response, it is possible that replacing a portion of dietary grass or legume forage with straw could maintain chewing activity as total forage proportion in the diet is reduced.

Therefore, the objective of this study was to determine the short-term effect of feeding lactating Holstein cows diets containing lower starch content (20.9% of dietary DM) and differing amounts of forage (52, 47, 43, and 39% of DM) on lactation performance, chewing activity, ruminal fermentation and dynamics, microbial nitrogen yield, and total-tract nutrient digestibility. We hypothesized that reduced dietary forage percentage when combined with a lower starch diet and inclusion of chopped wheat straw would support chewing activity, ruminal function, and SCM production similar to higher forage diets.

MATERIALS AND METHODS

Animal Use and Handling

Eight primiparous (4 ruminally fistulated) and 8 multiparous (4 ruminally fistulated) Holstein cows, averaging 116 ± 5 DIM and 1.9 ± 0.3 lactations, were housed in individual tie stalls at the William H. Miner Agricultural Research Institute (Chazy, NY) from August 1 to October 24, 2008. Cows were stratified by parity, fistulation status, and milk production and used in a replicated 4 × 4 Latin square design to evaluate the effects of decreasing forage content of lower starch diet. Each square consisted of four 21-d periods with 12 d of adjustment to treatment followed by 9 d of data collection. Animal care and handling protocols were approved by the William H. Miner Agricultural Research Institute Animal Care and Use Committee.

Diet Formulation

Dietary treatments (Table 1) were formulated to contain 21% starch and vary in forage content (52, 47, 43, and 39% of DM). Diets were formulated using the CPM-Dairy nutrition model (version 3.0; Cornell University, Ithaca, NY; University of Pennsylvania, Philadelphia, PA; and William H. Miner Agricultural Research Institute, Chazy, NY) to supply the required nutrients for a lactating Holstein cow weighing 578 kg with a BCS of 3.0, at 90 DIM consuming 22.0 kg/d of DM, and producing 40.8 kg/d milk containing 3.8% fat and 3.0% true protein. These values ensured that first-lactation animals would have an adequate supply of required nutrients. Diets were formulated such that, as corn silage and haycrop silage content of the diets decreased, wheat straw inclusion increased. The concentrate portion of the diets was adjusted to maintain similar concentrations of starch, other carbohydrate fractions, and protein fractions (Tables 2 and 3). Diets were delivered as a TMR once daily (1030 h; Calan Data Ranger; American Calan Inc., Northwood, NH) allowing for ad libitum intake; free access to fresh water was provided. Dry matter intake was determined by difference from feed offered and refused for each cow during each data collection period.

Milk Production and Composition

Cows were milked 3 times daily (0430, 1230, and 2030 h). Milk yields were recorded electronically (ProVantage Information Management System; Bou-Matic, Madison, WI) on d 13 to 19 of each period. Milk samples from 6 consecutive milkings for each cow were collected on d 16 (1230 and 2030 h), d 17 (0430, 1230, and 2030 h), and d 18 (0430 h) of each period. The first 3 consecutive milk samples and the last 3 consecutive milk samples were separately composited in proportion to milk yield at each sampling and preserved (Bronolab-W II Liquid Preservative; D&F Control Systems Inc., Dublin, CA). Composited milk samples were analyzed for fat, true protein, lactose, SNF, urea N, and SCC by infrared procedures (Dairy One, Ithaca, NY; Foss 4000; Foss Technology, Eden Prairie, MN).

BW and BCS

Body weight was measured (ID3000 indicator and MP600 58.4-cm load bars; Tru-Test Inc., Mineral Wells, TX) and BCS assigned in 0.25-unit increments on a scale of 1 to 5 (Ferguson et al., 1994) for each cow at d 1 and 19 (1200 h) of each period. Three trained individuals assigned BCS independently throughout the study.