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Effects of corn-based reduced-starch diets using alternative carbohydrate sources on performance of lactating Holstein cows

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ABSTRACT

Increases in grain prices have led to renewed interest in feeding reduced-starch diets to lactating dairy cows. An experiment was conducted to determine the effects of altering carbohydrate sources and reducing dietary starch on lactational performance, feeding behavior, and ruminal measures of Holstein dairy cows. Fifteen multiparous cows (6 ruminally cannulated) were blocked and assigned to 1 of 5 squares and used in a replicated 3 × 3 Latin square design with 21-d periods. Cows were fed 1 of 3 experimental diets: a control diet containing 20% brown midrib corn silage, 20% conventional corn silage, and 10% hay crop silage (CON); a reduced-starch high-forage diet containing 53% brown midrib corn silage and 10% hay crop silage (HFOR); and a reduced-starch diet containing the same forages as CON with partial replacement of corn meal by nonforage fiber sources (HNFFS). The CON diet contained (% of dry matter) 26.0% starch and 34.7% neutral detergent fiber (NDF), whereas the HFOR and HNFFS diets contained 21.4 or 21.3% starch and 38.3 or 38.0% NDF, respectively. Dry matter intake tended to be greater for cows fed the CON diet (28.2 kg/d) compared with those fed the HFOR diet (27.2 kg/d). Dry matter intake for cows fed the HNFFS diet was intermediate (27.7 kg/d). Milk yield was greater for cows fed the CON diet (51.6 kg/d) compared with those fed the HFOR diet (48.4 kg/d), but milk fat content tended to increase for cows fed the HFOR diet (3.98%) compared with those fed the CON diet (3.66%). Consequently, fat-corrected and solids-corrected milk yields were unaffected by dietary treatments. Total chewing, eating, and rumination times were similar across all dietary treatments. Rumination time per kilogram of DM was greatest for the HFOR diet, intermediate for the HNFFS diet, and least for the CON diet, whereas rumination time per kilogram of NDF was greatest for the CON diet and least for the HNFFS diet. Mean ruminal pH, NH_3-N (mg/dL), and total volatile fatty acid concentrations (m*M*) were similar across all dietary treatments. Molar proportion of ruminal acetate (mol/100 mol) was increased for cows fed the HFOR diet compared with cows fed the CON diet. Microbial N yield measured by urinary purine derivatives was unaffected by dietary treatment. Reduced-starch diets containing greater amounts of high quality, highly digestible forage or nonforage fiber sources in place of corn meal resulted in similar fat-corrected or solids-corrected milk yield for high-producing dairy cows in the short term.
Key words: feeding behavior, lactation, ruminal measures, starch

INTRODUCTION

Corn grain prices have trended higher over the past several years, and projections are for continued higher priced corn in the future (USDA–NASS, 2014). Consequently, formulating reduced-starch diets has become more economical. Common strategies for reducing dietary starch include the partial replacement of grain with highly digestible forage such as corn silage or a nonforage fiber source such as beet pulp, soybean hulls, or wheat middlings. Because both dietary formulation approaches could be economical, depending on the cost of the forage or nonforage fiber sources compared with corn grain, it is important to directly compare the responses of cows fed reduced-starch diets based on either strategy with diets containing more traditional amounts of starch (25 to 30% of DM).

Reducing dietary starch and increasing physically effective fiber in lactating dairy cow diets can have positive effects on ruminal health by increasing rumination, saliva flow, buffering capacity, and ruminal pH (Allen, 1997; Mertens, 1997). Previous studies have evaluated the partial replacement of corn meal with corn silage (Dann et al., 2008; Agle et al., 2010; Weiss et al., 2011) or nonforage fiber sources (Voelker and Allen, 2003a; Ferraretto et al., 2011; Dann et al., 2014). In these studies, reducing dietary starch using either formulation strategy consistently resulted in similar FCM yields

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with minor or no change in feed efficiency compared with normal-starch diets. However, direct comparisons of the effects of normal-starch compared with reduced-starch diets using both formulation strategies within the same study are limited.

The objectives of this experiment were to compare the effects of feeding a normal-starch diet with reduced-starch diets where corn meal was replaced with a highly digestible forage or nonforage source of fiber. Measurements of interest were lactational performance, feeding behavior, and ruminal measures of Holstein dairy cows. We hypothesized that these reduced-starch diets would result in similar FCM yield, improved milk fat yield, increased rumination time, and increased ruminal pH compared with a normal-starch diet.

MATERIALS AND METHODS

Experimental Design, Diets, and Management of Cows

This experiment was conducted at the William H. Miner Agricultural Research Institute (Chazy, NY) from September 16 to November 18, 2011. All procedures involving animals were approved by the William H. Miner Agricultural Research Institute Animal Care and Use Committee. Fifteen multiparous cows (6 ruminally cannulated) were blocked and assigned to 1 of 5 squares by ruminal fistulation status, DIM, and pre-experiment milk yield and used in a replicated 3 × 3 Latin square design with 21-d periods with all squares conducted concurrently. The first 14 d served as the dietary adaptation period and the last 7 d served as the collection period. Cows were (mean ± SD) 711 ± 87 kg of BW, 103 ± 24 DIM, and 2.7 ± 1.1 parities at the beginning of the experiment.

Three diets were formulated to contain varying concentrations of digestible NDF through use of brown midrib (**BMR**) corn silage, conventional corn silage, and hay crop silage. The 3 dietary treatments (Table 1; DM basis) were (1) a control diet containing 50% forage composed of 20% conventional corn silage, 20% BMR corn silage, and 10% hay crop silage (**CON**); (2) a high-forage diet containing 63% forage composed of 53% of the same BMR corn silage and 10% of the same hay crop silage (**HFOR**); and (3) a diet containing 50% forage composed of the same forages as the control diet, but with partial replacement of corn meal and soybean meal with nonforage fiber sources including beet pulp, wheat middlings, and dried distillers grains plus solubles (**HNFFS**). Soybean meal was reduced in the HFOR and HNFFS diets to ensure that all diets were isonitrogenous. The CON diet was formulated to contain (% of DM) 31% NDF and 27% starch, the HFOR diet was formulated to contain 35% NDF and 20% starch, and the HNFFS diet was formulated to contain 36% NDF and 20% starch. Diets were formulated with the CPM-Dairy nutrition model (version 3.0; Cornell University, Ithaca, NY; University of Pennsylvania, Philadelphia, PA; William H. Miner Agricultural Research Institute, Chazy, NY). The cow description used for formulation was a multiparous (second lactation) cow 103 DIM with a BCS of 3.00, BW of 710 kg, DMI of 27.2 kg/d, and milk yield of 50.3 kg/d containing 3.8% fat and 3.1% true protein. The model-predicted MP was 3,075, 2,978, and 3,007 g/d for the CON, HFOR, and HNFFS diets, respectively.

Cows were housed in a tiestall barn equipped with mattresses, individual feed boxes, and individual water bowls. Cows were fed for ad libitum intake (target of 5% orts) once daily at 1500 h, and feed was pushed up at 0700 h. The dietary treatments were prepared in a Calan Data Ranger (American Calan Inc., Northwood, NH). Cows were milked 3 times daily (0430, 1230, and 2030 h) in a double-12 parallel milking parlor (Xpressway Parallel Stall System; BouMatic, Madison, WI).

Data Collection, Sampling Procedures, and Analytical Methods

Individual feed ingredients were collected weekly and dried in a forced-air oven at 105°C for 18 to 24 h for DM determination. Diets were adjusted for changes in DM content of the feed ingredients when a feed ingredient DM value was outside the range of the DM mean ± 1.2 standard deviations or when a new feed ingredient source was used. Feed ingredients were also collected daily from d 15 to 21, and a portion of each sample was dried in a forced-air oven at 105°C for 18 to 24 h for DM determination. The remaining portion of each sample collected was frozen at −20°C and then composited by period on an equal-volume basis for chemical analysis.

Composites of feed ingredients and diets were analyzed for chemical composition by a commercial laboratory (Cumberland Valley Analytical Services Inc., Hagerstown, MD). Analyses included DM, OM (method 942.05; AOAC International, 2012), CP (method 990.03; AOAC International, 2012), soluble protein according to Krishnamoorthy et al. (1982), fat (method 2003.05; AOAC International, 2012), ADF (method 973.18; AOAC International, 2012), NDF using α-amylase but excluding sodium sulfite (Van Soest et al., 1991), ADL (Goering and Van Soest, 1970), starch according to Hall (2009), and minerals (method 985.01; AOAC International, 2012). Sugar was determined as described by Hall et al. (1999) with modifications. Sugar was measured as ethanol-soluble carbohydrates after a 2-h extraction with 80:20 (vol/vol) ethanol/water while ag-