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Effects of corn-based diet starch content and neutral detergent fiber source on lactation performance, digestibility, and bacterial protein flow in dairy cows

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ABSTRACT

An experiment was conducted to evaluate the effects of corn-based dietary starch content and source of neutral detergent fiber (NDF) on lactation performance, nutrient digestion, bacterial protein flow, and ruminal parameters in lactating dairy cows. Eight ruminally cannulated multiparous Holstein cows averaging 193 ± 11 d in milk were randomly assigned to treatments in a replicated 4 × 4 Latin square design with 21-d periods. Treatment diets were high corn grain (HCG; 38% corn silage, 19% dry ground corn, and 4% soy hulls), high soy hulls (HSH; 38% corn silage, 11% dry ground corn, and 13% soy hulls), high corn silage (HCS; 50% corn silage, 6% dry ground corn, and 4% soy hulls), and low corn silage (LCS; 29% corn silage, 15% corn, and 19% soy hulls). The HCG, HSH, HCS, and LCS diets contained 29, 23, 24, and 22% starch; 27, 32, 30, and 32% total NDF; and 21, 21, 25, and 17% forage NDF (dry matter basis), respectively. Mean dry matter intake and milk yield were unaffected by treatment. Cows fed LCS had reduced milk fat content compared with HSH and HCS. The concentration of milk urea nitrogen was greater for cows fed HCS compared with the other treatments. Total-tract digestion of NDF was reduced for cows fed the HCG diet. Total-tract starch digestion was increased for cows fed the HSH and HCS compared with HCG and LCS diets. Bacterial protein flow was unaffected by treatment. Ruminal ammonia concentration was reduced in cows fed the HCG and LCS diets compared with the HCS diet. Ruminal propionate increased and the acetate:propionate ratio decreased in cows fed the LCS diet compared with the HCS diet. Ruminal pH was greater for cows fed the HCS diet compared with cows fed the LCS diet. Diet digestibility and performance of mid- to late-lactation cows fed reduced-starch diets by partially replacing corn grain with soy hulls or corn silage was similar to or improved compared with cows fed a normal-starch diet.

Key words: lactation, neutral detergent fiber, reduced-starch diet

INTRODUCTION

The increasing cost of corn grain has led to renewed interest in feeding reduced-starch diets to lactating dairy cows. Reduced-starch diets are typically formulated by partially replacing corn grain with nonforage fiber sources (**NFFS**) such as citrus pulp, corn gluten feed, soy hulls, or wheat middlings; or with forages such as barley silage, corn silage, hay or haycrop silages. Several studies have investigated the effect of replacing high-moisture corn or dry ground shelled corn with NFFS (Ranathunga et al., 2010; Ferraretto et al., 2012; Akins et al., 2014) or forages (Oba and Allen, 2003a; Dann et al., 2008; Agle et al., 2010) on animal performance. The NDF from NFFS is more digestible than that from forages (Ipharraguerre et al., 2002; Bradford and Mullins, 2012). However, NDF from forage provides more physically effective NDF because of larger particle size and lower particle density, potentially leading to increased rumination activity, improved rumen function, and increased milk fat (Mertens, 1997), but may also reduce DMI due to rumen fill (Allen, 2000). Direct comparisons between the 2 approaches for reducing dietary starch content are limited. Weiss (2012) replaced 25% (DM basis) of concentrates with corn milling product or 25% and 40% of a combination of forage and concentrate with corn milling product. Replacement of concentrate with the corn milling product resulted in an increase in DMI (22.8 to 24.1 kg/d), a tendency for a decrease in milk yield (42.0 to 40.3 kg/d), but an increase in milk fat yield (1.18 to 1.40 kg/d). Replacement of forage and concentrate with the corn milling product resulted in a linear increase in DMI (22.8 to 24.4 and 25.1 kg/d) and a quadratic response in milk fat yield (1.18 to 1.24 and 1.17 kg/d), whereas milk yield was unaffected. Further comparisons of the partial replacement of corn grain or forage with alternative NFFS are needed to identify optimal ration formulation strategies when reduced-starch diets are fed.

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Poor weather conditions, such as drought or excessive rainfall, or alfalfa winterkill can result in inadequate forage inventories for dairy producers. Depleted forage inventory may require feeding lower amounts of forage and offsetting the forage in diets with purchased feeds. An associated increase in the cost of corn grain and the inability to readily purchase forages may result in the need to partly replace forage and corn grain with NFFS. However, comparisons of partially replacing forage and corn grain with NFFS for lactating dairy cows are limited (Boddugari et al., 2001; Mullins et al., 2010; Sullivan et al., 2012).

Experimental objectives were to compare the effects of partly replacing dietary starch with different sources of NDF on lactation performance, nutrient digestibility, bacterial protein flow, and ruminal parameters. Our hypothesis was that the partial replacement of corn grain with NFFS or corn silage and partial replacement of corn grain and silage with NFFS would maintain milk yield and improve milk fat yield in mid- to late-lactation cows.

MATERIALS AND METHODS

Animal Management and Experimental Design

All experimental protocols were approved by the Animal Care and Use Committee of the College of Agriculture and Life Sciences at the University of Wisconsin-Madison (protocol no: A01471-0-04-11). Eight multiparous Holstein cows averaging 651 ± 45 kg of BW and 193 ± 11 DIM at trial initiation, fitted with rumen cannulas (Bar Diamond, Parma, ID) measuring 10.2 cm in diameter were randomly assigned to a replicated 4 × 4 Latin square design. Experimental periods lasted 21 d, with 15 d for adaptation and 6 d for sample collection. Experimental diets included a normal-starch diet containing dry ground shelled corn (**HCG**) and reduced-starch diets formulated by partially replacing dry ground shelled corn with soy hulls (**HSH**) or corn silage (**HCS**) or by partially replacing corn silage and corn grain with soy hulls (**LCS**). Ingredient compositions of the experimental diets are in Table 1. Trace minerals and vitamins were supplemented to meet or exceed NRC (2001) guidelines.

Cows were housed on bedded mattresses in a tiestall barn in the Dairy Cattle Center at the University of Wisconsin-Madison. Cows were milked twice daily in a parlor at 0700 and 1900 h, with yields recorded at each milking for each cow. Milk samples were collected from each cow for 4 consecutive milkings on d 16 and 17 and analyzed for fat, true protein, lactose, and MUN concentrations using infrared analysis (method 972.16; AOAC International, 2012; AgSource Milk Analysis Laboratory, Menomonie, WI) using a Foss Milko-Scan FT6000 (Foss Electric, Hillerød, Denmark). Fat-corrected milk and ECM were calculated from average milk yield during the treatment period and average milk fat and protein content according to NRC (2001). Cows were fed a TMR individually twice daily at 1000 and 1900 h for a target of 5% refusals with the amounts fed and refused recorded daily. The corn silage, alfalfa silage, and concentrate mix DM content was determined weekly with the as-fed proportions adjusted as necessary to maintain the desired DM proportions of the ingredients in the TMR.

Sampling and Laboratory Analysis

Subsamples of TMR and refusals for each cow were collected on d 19 to 21 of each period. The TMR, refusals, and diet ingredients sampled weekly were dried at 60°C for 48 h in a forced-air oven to determine DM content, and ground to pass a 1-mm screen using a Wiley mill (model #4; Thomas Scientific, Swedesboro, NJ). Composites of diet ingredients, TMR for each experimental diet, and refusals for each cow were made by period for analyses at a commercial feed testing laboratory (Dairyland Laboratories Inc., Arcadia, WI). Analyses included DM, OM (method 942.05; AOAC International, 2012), CP (method 990.03; AOAC International, 2012), ether extract (method 2003.05; AOAC International, 2012), NDF using α-amylase and sodium sulfite (Van Soest et al., 1991), and starch (Bach Knudsen, 1997; YSI Biochemistry Analyzer; YSI Inc., Yellow Springs, OH). Composites of alfalfa silage, corn silage, and soy hulls obtained before blending of experimental concentrate mixes were analyzed for in vitro NDF digestibility after 30-h incubations (Holden, 1999). Prolamin protein was determined on dry ground corn obtained before blending of experimental concentrate mixes (Larson and Hoffman, 2008). Composites of corn silage and dry ground corn were analyzed for in vitro starch digestibility after 7-h incubations (Richards et al., 1995). Particle size of the dry ground corn samples were determined by dry sieving using a Tyler Ro-Tap Shaker (model RX-29, Tyler, Mentor, OH) containing sieves with 4,760-, 2,380-, 1,190-, 595-, 297-, 149-, and 63-μm apertures plus a bottom pan, with mean particle size calculated using a log normal distribution (Baker and Herrman, 2002).

Digesta flow from the rumen was quantified using the omasal sampling technique (Huhtanen et al., 1997; Ahvenjärvi et al., 2000). The omasal digesta markers included indigestible NDF (**iNDF**; Huhtanen et al., 1994) for the large particle phase (**LP**), $YbCl_3$ (Siddons et al., 1985) for the small particle phase (**SP**), and Cr-EDTA (Udén et al., 1980) for the fluid phase