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Effects of corn-based diet starch content and corn particle size on lactation performance, digestibility, and bacterial protein flow in dairy cows

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ABSTRACT

An experiment was conducted to determine the effects of dietary starch content in corn-based diets and corn particle size on lactation performance, nutrient digestibility, and bacterial protein flow in dairy cows using the omasal and reticular sampling technique. Eight ruminally cannulated lactating multiparous Holstein cows were used in a replicated 4 × 4 Latin square design with a 2 × 2 factorial arrangement of treatments. Treatments were fine (FG; mean particle size = 552 μm) and coarse (CG; 1,270 μm) ground dry shelled corn in normal- (NS) and reduced- (RS) starch diets fed as total mixed rations. The NS and RS rations contained 27 and 18% starch (dry matter basis), respectively, and were formulated by partially replacing corn with soy hull pellets. Mean dry matter intake was unaffected by treatment (23.2 kg/d). Cows fed NS diets produced 1.9 kg/d more milk and 0.06 kg/d more milk protein compared with cows fed RS diets. Cows fed NSFG and RSCG diets produced more fat-corrected milk than did cows fed NSCG and RSFG diets. Milk urea concentration was decreased for cows fed NS diets (12.4 mg/dL) compared with RS diets (13.5 mg/dL). Ruminal digestibility of neutral detergent fiber (NDF; % of NDF intake) determined by the omasal sampling technique was increased in cows fed RS diets compared with NS diets (43.4 vs. 34.9%), and total-tract digestibility of NDF (% of NDF intake) was increased in cows fed RS diets compared with those fed NS diets (50.1 vs. 43.1%). Ruminal digestibility of starch (% of starch intake) determined by the omasal sampling technique was greater in cows fed NS diets compared with those fed RS diets (85.6 vs. 81.6%). Total-tract starch digestion was increased in cows fed RS diets compared with those fed NS diets (96.9 vs. 94.6%) and in cows fed FG diets compared with those fed CG diets (98.0 vs. 93.5%). Bacterial protein flow was unaffected by treatment. The omasal and reticular sampling techniques resulted in similar treatment effects for nutrient flow and digestibility, although nutrient flow was lower and nutrient digestibility was greater in cows when sampled by the omasal technique compared with the reticular technique. Cows fed FG diets had greater ruminal propionate, lower acetate:propionate ratio, and lower pH. Feeding NS diets increased milk and protein yields and feeding finely ground corn increased ruminal propionate concentration.

Key words: corn, lactation, reduced starch, particle size

INTRODUCTION

Increases in corn prices have increased the interest in feeding reduced-starch diets to lactating dairy cows. Longer term continuous-lactation trials (12 wk) comparing normal- and reduced-starch diets have reported similar or reduced milk yields, similar or greater DMI, similar or reduced milk protein, and similar or reduced feed efficiency (kg of milk yield/kg of DMI; Gencoglu et al., 2010; Ferraretto et al., 2011, 2012; Akins et al., 2014) for cows fed corn-based, reduced-starch diets. Estimates of ruminal nutrient digestion and bacterial protein flow when reduced-starch diets are fed may help us better understand the effects of these feeding strategies and allow for dietary adjustments and improvements in animal performance.

Reduced-starch diets typically result in greater total-tract starch digestibility because a greater portion of dietary starch often comes from more digestible feed ingredients such as corn silage (Ferraretto and Shaver, 2012). Starch digestibility is also affected by several factors such as particle size, grain processing, and moisture content (Firkins et al., 2001; Ferraretto et al., 2013). Furthermore, harvest maturity, duration of silo fermentation (Hoffman et al., 2011), and corn endosperm type (Taylor and Allen, 2005; Lopes et al., 2009) influence starch digestibility. Diets with finely ground dry corn grain have improved total-tract starch digestibility, with varying effects on DMI, milk yield, and fat yield (Knowlton et al., 1998; Yu et al., 1998; Rémond et al., 2004). Feeding more digestible corn grain in reduced-starch diets may result in greater milk yield, improved feed efficiency, and similar fat yield

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and animal performance compared with normal-starch diets.

The objectives of this study were to evaluate the effects of feeding normal- or reduced-starch diets and fine or coarse ground dry shelled corn on lactation performance, digestion, bacterial protein flow, and ruminal parameters by dairy cows. We hypothesized that feeding finely ground corn grain compared with coarsely ground corn grain would result in increased milk yield, starch digestibility, and bacterial protein flow. Furthermore, feeding reduced-starch diets compared with normal-starch diets would result in similar FCM yields and increased starch digestibility.

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. Eight multiparous Holstein cows averaging 584 ± 29 kg of BW and 96 ± 8 DIM at trial initiation, fitted with ruminal cannulas (Bar Diamond, Parma, ID) measuring 10.2 cm in diameter, were randomly assigned to a replicated 4 × 4 Latin square design with a 2 × 2 factorial arrangement of treatments. Experimental periods lasted 21 d and consisted of a 14-d adaptation period and 7 d for sample collection. Experimental diets included a normal-starch (**NS**) ration or a reduced-starch (**RS**) ration formulated by partially replacing dry ground shelled corn and a small amount of soybean meal with soy hull pellets (**SH**) to provide isonitrogenous diets. The NS and RS diets contained either finely ground (**FG**) or coarsely ground (**CG**) dry shelled corn for experimental diets of NS with FG corn (**NSFG**), NS with CG corn (**NSCG**), RS with FG corn (**RSFG**), and RS with CG corn (**RSCG**). 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 BouMatic Side-Opening single 4 parlor (Boumatic, Madison, WI) at 0700 and 1900 h, with milk yield recorded at each milking for each cow. Milk samples were collected from each cow for 4 consecutive milkings on d 16 and 17 of each treatment period and analyzed for fat, true protein, lactose, and MUN concentrations by 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 individually fed a TMR twice daily at 1000 and 1900 h for a target of 5% refusals, with the amounts fed and refused recorded daily. The DM contents of alfalfa silage, corn silage, dry ground corn, and NS and RS concentrate mix were 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 were collected on d 18 to 20 and d 19 to 21, respectively, for each cow every period. The TMR and 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

Table 1. Dietary ingredient and nutrient composition

Item	Normal starch	Reduced starch
Ingredient, % of DM		
Alfalfa silage	29.5	29.9
Corn silage	22.6	22.9
Ground corn grain	25.2	13.2
Concentrate mix	22.7	34.0
Concentrate mix, % of DM		
Soy hulls	11.5	43.8
Soybean meal, 48%	23.4	12.1
Soybean meal, expeller[1]	27.8	18.8
Dried distillers grains	24.7	16.8
Partially hydrogenated tallow[2]	3.5	2.4
Calcium carbonate	2.29	1.53
Sodium bicarbonate	1.72	1.15
Monocalcium phosphate	1.41	0.94
Magnesium oxide	1.06	0.71
Trace mineral salt[3]	1.89	1.26
Vitamin premix[4]	1.06	0.71
Nutrient composition		
DM, % as fed	54.8	54.4
CP, % of DM	17.1	17.3
NDF, % of DM	26.5	33.8
Forage NDF, % of DM	19.9	19.9
Ether extract, % of DM	3.7	3.3
Ash, % of DM	7.4	8.0
NFC,[5] % of DM	45.7	37.9
Starch, % of DM	26.5	18.2

[1]Exceller meal (Quality Roasting Inc., Valders, WI).

[2]Energy Booster (Milk Specialties Global Animal Nutrition, Carpentersville, IL).

[3]88% NaCl; 0.002% Co; 0.2% Cu; 0.012% I; 0.18% Fe; 0.8% Mn; 0.006% Se; 1.4% Zn.

[4]Vitamin A 3,300,000 IU/kg; vitamin D 1,100,000 IU/kg; vitamin E 11,000 IU/kg.

[5]Calculated as 100 – (CP % + NDF % + ether extract % + ash %; NRC, 2001).