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Corn Grain Endosperm Type and Brown Midrib 3 Corn Silage: Site of Digestion and Ruminal Digestion Kinetics in Lactating Cows

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ABSTRACT

Interactions of endosperm type of corn grain and the brown midrib 3 (*bm3*) mutation in corn silage on ruminal kinetics and site of nutrient digestion of lactating dairy cows were evaluated. Eight ruminally and duodenally cannulated cows (72 ± 8 d in milk; mean ± SD) were used in a duplicated 4 × 4 Latin square design experiment with a 2 × 2 factorial arrangement of treatments. Treatments were corn grain endosperm type (floury or vitreous) and corn silage type (*bm3* or isogenic normal). Diets contained 26% neutral detergent fiber (NDF) and 30% starch. Interactions of treatments were not observed for any measure of digestibility, but digestion kinetics of starch and fiber did interact to affect digestible organic matter intake by affecting dry matter intake. Rate of ruminal starch digestion was faster and rate of ruminal starch passage tended to be slower in diets containing corn grain with floury vs. vitreous endosperm, resulting in a mean increase of 22 units for ruminal starch digestibility. Although compensatory postruminal starch digestion decreased differences among treatments for total tract starch digestibility, starch entering the duodenum was more digestible for grain with floury endosperm compared with vitreous grain, resulting in greater total tract starch digestibility for floury compared with vitreous corn grain. Fermentation rate of potentially digestible NDF was not affected by either *bm3* corn silage or greater ruminal starch digestion of floury grain. Brown midrib corn silage increased total tract NDF digestibility vs. control silage by numerically increasing ruminal and postruminal digestibility of NDF. Endosperm type of corn grain greatly influences site of starch digestion and should be considered when formulating diets.
(**Key words:** endosperm, brown midrib, starch digestibility)

Abbreviation key: ***bm3*** = brown midrib 3 mutation, **iNDF** = indigestible NDF, **pdNDF** = potentially digestible NDF.

INTRODUCTION

Ruminants have dietary requirements for forage to maximize production and ruminal health, but slower digestion and greater ruminal retention time of fiber can potentially limit DMI and milk yield. The brown midrib 3 mutation (***bm3***) in corn silage increases potential digestibility of fiber and allows for greater feed intake while providing forage fiber (Oba and Allen, 2000a). Although increased fiber digestibility can reduce the filling effect of fibrous feeds and might allow greater feed intake, *bm3* corn silage reduces ruminal pH and might reduce ruminal digestibility of potentially digestible NDF (**pdNDF**; Oba and Allen, 2000b).

Brown midrib 3 corn silage also reduced ruminal starch digestibility compared with its isogenic control corn silage because of greater ruminal starch passage rate in *bm3* corn silage diets (Oba and Allen, 2000b). This research indicates that *bm3* corn silage not only changes fiber digestibility but also has the potential to affect ruminal starch digestibility and thus site of starch digestion. Site of starch digestion can be manipulated by grain conservation method (Oba and Allen, 2003b), method of processing (Callison et al., 2001), and endosperm type of corn grain (Philippeau et al., 1999b). Flint corn, which has a higher proportion of vitreous endosperm, was digested more slowly and to a lesser extent than dent corn in the rumen of beef steers (Philippeau et al., 1999b). Endosperm type of corn grain varies widely across commercially available hybrids but is not considered when formulating diets for lactating dairy cows. Understanding how feedstuffs affect site of starch digestion is critical to commercial dairy production because manipulating site of starch digestion can alter feed intake (Allen, 2000), and ultimately milk production.

Controversy exists as to the benefits of ruminal vs. postruminal starch digestion. Ruminal starch digestion is needed to provide substrate for microbial growth and propionate as a glucose precursor for milk synthesis but can reduce ruminal pH and inhibit fiber digestibility if starch fermentation is too rapid. If ruminal starch degradation is too rapid, flux of propionate to the liver might limit DMI if it is oxidized rather than used for gluconeogenesis (Oba and Allen, 2003c). Shifting starch

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digestion to the intestines can theoretically provide more glucose to the animal but infusion experiments have suggested that increasing small intestinal glucose absorption may not increase glucose available for milk production (Knowlton et al., 1998; Arieli et al., 2001). Instead, increased glucose may be used for tissue retention (Reynolds et al., 2001) or may be oxidized to CO_2 (Knowlton et al., 1998). It is important to understand how chemical and structural aspects of dietary ingredients can affect starch and fiber digestibility and how they interact to affect ruminal kinetics and site of nutrient digestion.

We hypothesized that corn grain with floury endosperm is more rapidly degraded in the rumen compared with corn grain with vitreous endosperm and will decrease rate of digestion of pdNDF to a greater extent when combined with *bm3* corn silage compared with control corn silage. Furthermore, ruminal passage rate of starch will be increased by *bm3* corn silage compared with control corn silage. The objective of this experiment was to evaluate interactions of the brown midrib 3 mutation in corn silage and corn grain endosperm type on site of nutrient digestion and ruminal digestion kinetics in lactating dairy cows.

MATERIALS AND METHODS

This article is the first of 3 articles in a series from one experiment that evaluated effects of corn grain endosperm type and the brown midrib 3 mutation in corn silage. This article discusses treatment effects on site of nutrient digestion and ruminal digestion kinetics, and the companion articles focus on feeding behavior and milk production (Taylor and Allen, 2005a) and ruminal fermentation and microbial N efficiency (Taylor and Allen, 2005b). Experimental procedures were approved by the All University Committee on Animal Use and Care at Michigan State University.

Cows and Treatments

Eight multiparous Holstein cows (72 ± 8 DIM; mean ± SD) from the Michigan State University Dairy Cattle Teaching and Research Center were assigned randomly to treatment sequence within duplicate 4 × 4 Latin squares balanced for carryover effects. A 2 × 2 factorial arrangement of treatments was used with main effects of corn grain endosperm type (floury or vitreous) and *bm3* mutation in corn silage (present or absent). Treatment periods were 21 d, consisting of an 11-d diet adaptation period followed by 10 d of collection. Surgical preparation of ruminally and duodenally cannulated cows was performed after dry-off, approximately 50 d before calving. Duodenal cannulas were soft gutter type made of Tygon and vinyl tubing (Crocker et al., 1998). For each animal, the duodenum was fistulated distal to the pylorus region before the pancreatic duct, and the cannula was placed between 10th and 11th ribs as described by Robinson et al. (1985). Surgery was performed at the Department of Large Animal Clinical Science, College of Veterinary Medicine, Michigan State University. At the beginning of the experiment, empty body weight (ruminal digesta removed) of cows was 531.8 ± 43.9 kg (mean ± SD).

Two corn hybrids, 6208FQ and 657 (Cargill Hybrid Seeds, Minneapolis, MN), were planted for silage in the spring of 2001 at the Michigan State University Research Farm. The hybrids are isogenic except that Cargill 657 contains the *bm3* mutation. Cargill 6208FQ corn forage was harvested at 30.6% whole plant DM and chopped to 11-mm theoretical length of cut. Cargill 657 corn forage was harvested at 32.2% whole plant DM and chopped to 10-mm theoretical length of cut. The chop lengths of the 2 hybrids differed to achieve a similar particle size distribution as measured using a Penn State Particle Size Separator (Lammers et al., 1996). Both hybrids were ensiled in 12.4-m diameter AgBags oriented in a west to east direction; silage was removed from the east end to minimize the effects of wind on silage DM. Nutrient compositions and physical characteristics of the corn silage treatments used in the experiment are shown in Table 1.

Two corn hybrids varying in endosperm type (floury and vitreous) were planted for grain in the spring of 2001 at the Michigan State University Research Farm. The floury (SL53; Crow's Hybrid Corn Company, Kentland, IN) and vitreous (Z75W; Wilson Genetics, Harlan, IA) hybrids were selected based upon their high and low in vitro starch digestibility, respectively. Grains were harvested after field drying to ~20% DM, and were commercially dried at low temperature (< 32°C) to ~14% DM. The corn was ground and bagged for use in the experiment. Vitreousness (% of endosperm) for floury and vitreous corn grain was 3.0 and 67.2%, respectively (Table 2). Nutrient compositions and physical characteristics of the corn grain treatments used in the experiment are shown in Table 2.

Experimental diets contained dry ground corn treatments (floury or vitreous), corn silage (*bm3* or isogenic normal), alfalfa silage (10% of diet DM), whole linted cottonseed (7% of diet DM), a protein supplement premix (soybean meal, distillers grains, and blood meal), and a premix of minerals and vitamins. Experimental diets were fed as TMR and were formulated to contain 27% NDF, 18% CP, and minerals and vitamins to meet requirements according to NRC (2001). Ingredient and nutrient compositions of the experimental diets are shown in Table 3.