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The effects on digestibility and ruminal measures of chemically treated corn stover as a partial replacement for grain in dairy diets

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ABSTRACT

Alkaline treatment of gramineous crop residues can convert an abundant, minimally utilized, poorly digestible straw into a moderately digestible feedstuff. Given the volatile nature of grain prices, substitution of treated stover for grain was investigated with dairy cows to provide insights on ruminal and digestibility effects of a feed option that makes use of alternative, available resources. The objective of this study was to evaluate changes in diet digestibility and ruminal effects when increasing levels of calcium oxide-treated corn stover (CaOSt) were substituted for corn grain in diets of lactating cows. Mature corn stover was treated with calcium oxide at a level of 50 $g\cdot kg^{-1}$ dry matter (DM), brought up to a moisture content of 50% following bale grinding, and stored anaerobically at ambient temperatures for greater than 60 d before the feeding experiment. Eight ruminally cannulated Holstein cows averaging 686 kg of body weight and 35 kg of $milk\cdot d^{-1}$ were enrolled in a replicated 4 × 4 Latin square, where CaOSt replaced corn grain on a DM basis in the ration at rates of 0, 40, 80, and 120 $g\cdot kg^{-1}$ DM. All reported significant responses were linear. The DM intake declined by approximately 1 kg per 4% increase in CaOSt inclusion. With increasing replacement of corn grain, dietary neutral detergent fiber (NDF) concentration increased. However, rumen NDF turnover, NDF digestibility, NDF passage rate, and digestion rate of potentially digestible NDF were unaffected by increasing CaOSt inclusion. Total-tract organic matter digestibility declined by 5 percentage units over the range of treatments, approximately 1.5 units per 4 percentage unit substitution of CaOSt for grain. With increasing CaOSt, the molar proportions of butyrate and valerate declined, whereas the lowest detected ruminal pH increased from 5.83 to 5.94. Milk, fat, and protein yields declined as CaOSt increased and DM intake declined with the result that net energy in milk declined by approximately 1 Mcal per 4% increase in CaOSt. Time spent ruminating ($min\cdot kg^{-1}$ DM intake) increased with increasing CaOSt, though total minutes per day were unaffected. These insights on the effect of substitution of treated corn stover for corn grain may be used to predict the effect on nutrient supply to the cow over a range of substitution levels. The acceptability of the effect will depend on the economics of milk production and availabilities of feedstuffs.
Key words: corn stover, calcium oxide, alkaline, fiber digestibility

INTRODUCTION

Alkaline treatment of gramineous crop residues has been shown to be an effective method of enhancing digestibility of the secondary cell wall. The alkali agents are absorbed into the cell wall, where acetic and uronic acid ester bonds are saponified, breaking down linkages between lignin, hemicellulose, and cellulose (Jackson, 1977). Alkali agents also reduce the strength of intermolecular hydrogen bonds in cellulose fibrils, resulting in swelling of the cellulose (Jackson, 1977). These modes of action open up the cell wall and lead to increased bacterial adhesion to fiber particles and increased bacterial colonization, resulting in a greater degree of fiber degradation in the rumen. Previously, Haddad et al. (1994) demonstrated this effect with NaOH and $Ca(OH)_2$ treatment of wheat straw, which resulted in in the potentially digestible NDF (**pdNDF**) increasing from 51.2 to 81.2% and 73.5%, respectively, as a fraction of the total NDF. The rate of digestion was not affected and the in vitro lag time decreased with treatment. Others have also found increases in the extent of digestion of gramineous forages with alkaline treatments (Rexen and Vestergaard Thomsen, 1976; Wanapat et al., 1986; Canale et al., 1990).

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Recent interest in alkali treatment of corn stover has been focused on improving the quality and making use of this abundant, minimally utilized resource. Work in beef cattle showed that partial replacement of corn grain (35% of diet DM) with a mix of calcium oxide (CaO) treated corn stover and distillers grains had no effect on ADG or carcass characteristics (Russell et al., 2011). Donkin et al. (2012) found that in dairy cattle producing approximately 29 kg milk daily, CaO-treated corn stover could replace up to 25% of corn silage (DM basis) with no effect on milk production, intake, and milk composition.

Alkali-treated stover would most likely be considered a substitute for forage and other fibrous feeds in dairy cattle diets, given its composition and physical form. However, during some years, limited forage availability and grain production (USDA, 2013a) or high grain prices (up to \$570/t for corn grain; USDA, 2013b) force farmers to feed whatever feedstuffs are available to maintain their herds. A challenge in such cases is having information with which to estimate how feeds will perform in such diets with the larger, productive Holstein cows present on many farms today. Very limited information is available regarding the effect of substitution of fiber sources for grain in lactating cow diets (Hall and Chase, 2014), nor on the effect of alkali-treated stover used in such an exchange on digestibility and rumen function. Accordingly, the objective of this study was to evaluate the effects of partially replacing corn grain with CaO-treated corn stover on ruminal measures, total-tract nutrient digestibility, and time management of lactating dairy cows.

MATERIALS AND METHODS

CaO-Treated Corn Stover

Corn stover was harvested in a large round bale format, following postgrain harvest dry-down, and was stored aerobically until treatment. At the time of treatment, bales were processed through a tub grinder (Haybuster Model H1100, Duratech Industries, Jamestown, ND) with a 10.2-cm screen. The processed stover was mixed in a TMR mixer, where a CaO slurry was added to achieve the target 50 g of CaO (kg of stover DM)$^{-1}$ and 500 g of H_2O (kg of stover DM)$^{-1}$. Following thorough mixing, the treated stover was packed into a plastic silage bag using specialized mechanical equipment sized to fill and pack a 2.4 m in diameter silage bag (Ag-Bagger, Ag-Bag, St. Nazianz, WI) and stored anaerobically for at least 60 d, which is more than the required 7 d for effective treatment at ambient temperature and pressure (Shreck, 2013).

Cows and Diets

Eight ruminally cannulated lactating Holstein cows, averaging (mean ± SD) 108 ± 58 DIM, 686 ± 103 kg of BW, and 35.3 ± 4.6 kg of milk·d^{-1}, were randomly assigned to a replicated 4 × 4 Latin square. Treatment periods were 21 d, with 14 d for acclimation and the final 7 d of the period were used for sample and data collection. Treatments were linear increases in the partial replacement of dry corn grain with CaO treated corn stover in the diet. The 4 treatments (Table 1) were **TS0** (0% stover, and 18.6% grain), **TS4** (4.4% stover and 14.6% grain), **TS8** (8.6% stover and 10.7% grain), and **TS12** (12.9% stover and 6.7% grain). Ground limestone was added to the TS0, TS4, and TS8 diets to equalize dietary Ca concentrations across all treatments. The diet composition presented in Table 1 is that recorded from actual weighing of ingredients in the feeding system.

Diets were fed once daily at 0700 h as a TMR to the cows individually on an ad libitum basis. Milk production, feed offered, and orts were recorded daily throughout the experiment. All cows used in this study were maintained under protocols approved by the University of Wisconsin Institutional Animal Care and Use Committee. The cows were housed in a tie-stall barn bedded with rubber mattresses and chopped straw at the USDA-ARS US Dairy Forage Research Center Farm in Prairie du Sac, Wisconsin.

Sample Collection

Cows were milked twice daily at 0400 and 1600 h in a milking parlor. Milk was sampled for compositional analysis at both milkings on d 17, 18, and 19 of each period. Milk samples were analyzed for composition by AgSource Milk Analysis Laboratory (Menomonie, WI) using mid-infrared analysis with a Foss FT6000 instrument (method 972.12; AOAC, 1990). Milk energy density (as NE_L Mcal·kg^{-1}), was calculated from NRC equations (equations 2–15, NRC, 2001). Equivalent wet volume fecal samples were collected on d 17 through 19 of each period to represent sampling every 4 h over a 24-h cycle. The sampling commenced at 0300 h on d 17 and continued at 1500 h (d 17), 0700 h (18 d), 1900 h (18 d), 1100 h (19 d), and 2300 h (19 d). Fecal samples were dried at 55°C and then composited by cow within period. At the 0700 h sampling (d 18), pH was taken on fecal samples before drying, using an electronic pH meter (315i; WTW Wissenschaftlich-Technische Werkstätten GmbH, Weilheim, Germany).

Rumen fluid was sampled below the ruminal mat from the ventral area of the rumen, on d 16 every hour