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The effects of calcium hydroxide–treated whole-plant and fractionated corn silage on intake, digestion, and lactation performance in dairy cows

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ABSTRACT

The objective of this trial was to evaluate, in dairy cattle, the effects of calcium hydroxide treatment of whole-plant corn and a treatment applied to the bottom stalk fraction of the corn plant, achieved by harvesting corn in 2 crop streams. The treatments were calcium hydroxide–treated corn silage (TRTCS), toplage supplemented with calcium hydroxide–treated stalklage (TPL), a positive control of brown midrib corn silage (BMR), and a negative control of conventional whole-plant corn silage (WPCS). The toplage was harvested at a height of 82 cm with 2 of the 6 rows set as ear-snapping to incorporate higher tissues into the stalklage. Stalklage was harvested at 12 cm, and other corn silages were harvested at 27 cm. Sixteen pens, each with 8 Holstein cows averaging 70 ± 25 d in milk and 46 ± 11 kg of milk d^{-1}, were assigned 4 per treatment in a completely randomized design. The diet was approximately 40% corn silage, 20% alfalfa silage, and 40% concentrate on a dry matter basis. A 2-wk covariate period with conventional corn silage was followed by an 8-wk treatment period in which the 4 corn silage treatments were the only effective difference in diets. Cows fed TPL and TRTCS consumed more (1.9 and 1.4 kg of OM d^{-1}, respectively) than did cows fed WPCS. Milk yield was greater for cows fed BMR, TPL, and TRTCS. Cows fed BMR and TPL produced 2.9 and 2.7 kg d^{-1}, respectively, more energy-corrected milk (ECM) than cows fed WPCS, and cows fed TRTCS had the greatest ECM production (4.8 kg of ECM d^{-1} greater than cows fed WPCS). No differences in body weight or body condition scored were observed. Milk fat concentration was similar among treatments and milk protein concentration was reduced for TRTCS. Starch and neutral detergent fiber digestibility were greater for cows fed TRTCS.
Key words: alkali, calcium hydroxide, fractionated, corn silage, fiber digestibility

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INTRODUCTION

Increased digestibility of fiber and starch can improve dairy lactation performance (Oba and Allen, 1999, 2000a; Schwab et al., 2002; Ferraretto and Shaver, 2015). Increases in digestibility can be accomplished by crop selection, earlier maturity harvest, improved storage management, physical treatment and size reduction, or chemical treatment, among other approaches (Fahey et al., 1993). The use of calcium hydroxide has been proven to improve fiber digestibility of gramineous crop residue (Jackson, 1977; Haddad et al., 1994, 1998; Shreck, 2013). However, the aerobic stability of alkali-treated silage at moisture contents greater than 400 g kg^{-1} can negate benefits of treatment (Deschard et al., 1988).

Corn harvested in 2 fractions allows for new ration formulations and targeting of low-quality roughage to animals such that their performance is not negatively affected. Corn silage with higher levels of starch and with higher fiber digestibility could replace whole-plant corn silage and some of the corn in a lactating dairy diet. Whole-plant corn silage (**WPCS**) containing highly digestible NDF can reduce the limitations of rumen fill, thereby allowing for greater intake and production (Mertens, 1987; Oba and Allen, 1999). Treated stalks could be used in late lactation, the dry period, and in heifer diets.

Brown midrib (**BMR**) mutant lines of corn have improved fiber digestibility, primarily due to a reduction in the lignin concentration of the NDF (Jung et al., 2012). Brown midrib lines can also suffer from lower yields, susceptibility to lodging, poor early season vigor, and slower early season growth rates (Miller et al., 1983). Mechanical and chemical treatments of corn silage can improve fiber digestibility while avoiding the agronomic disadvantages of BMR; however, such treatments result in increased costs and logistical harvest challenges.

The purpose of this study was to evaluate the effects of alkali treatment of corn fiber on the performance of lactating dairy cows in relation to a positive and negative control. The alkali treatment primarily exerts its effect by increasing the proportion of potentially digestible fiber, similar to BMR corn (Haddad et al., 1994, 1998; Oba and Allen, 2000a). The lower portion of the corn stalk contains the highest concentration of indigestible fiber. We hypothesize that feeding corn silage where the lower portion of the plant is treated with calcium hydroxide will improve intake and production over that of untreated corn silage, similar to BMR corn. We further hypothesize that whole-plant corn treated with calcium hydroxide will improve milk production to a greater degree than partial plant treatment.

MATERIALS AND METHODS

Crops and Harvest

A conventional corn, Pioneer P9910AMX [99 d comparative relative maturity (CRM); Pioneer, Johnston, IA], and a BMR corn hybrid containing the *bm3* gene mutation, Mycogen F2F499 (99 d CRM; Mycogen Seeds, Indianapolis, IN), were planted on May 30 and 31, 2014, respectively, at the University of Wisconsin–Arlington Agricultural Research Station (Arlington, WI). Crops were grown under the same tillage, fertilizer application, and weed control practices. All corn crops were harvested between September 30, 2014 and October 1, 2014, using a self-propelled forage harvester (JD 6950, John Deere, Moline IL) set for a 1.95-cm theoretical length of cut and equipped with conventional processing rolls set for a 2-mm clearance. Harvest was conducted at stubble heights of 26, 26, and 28 cm for conventional WPCS, BMR whole-plant corn silage, and calcium hydroxide–treated corn silage, respectively. Two new products were harvested using an ear-snapping head that uses a modified deck plate to harvest a mechanically adjustable proportion of the top of the plant and the ear in the first pass, yielding toplage (Nigon et al., 2016). For this study, 2 rows had only the ear harvested and 4 rows were harvested at a height of 82 ± 5 cm. In a second pass, the remaining stalks were cut using a windrower (JD 4995, John Deere) at a height of 12 ± 2 cm. Following a day of field wilting, in a third pass, a self-propelled forage harvester (JD 6950, John Deere) with a windrow pickup head was used to harvest the stalk fraction of the corn plant, yielding stalklage. Of the total harvested fraction, stalklage comprised 17.8% of the harvested DM and toplage 82.2% of the harvested DM. The conventional corn used for WPCS, toplage, stalklage, and calcium hydroxide–treated corn silage was harvested in series from multiple locations in the field to reduce field location variation. The BMR corn was grown in an immediately adjacent field under similar soil, fertility, and topographic conditions.

Dry matter content of the crops at harvest was 440, 395, 395, 336, and 336 g of DM (kg of fresh matter)$^{-1}$ for toplage, WPCS, calcium hydroxide–treated corn silage, BMR, and stalklage (Table 1), respectively. Whole-plant corn and the stalks destined for alkali treatment were harvested directly into a reel-type TMR mixer (Kuhn RC295, Kuhn North America, Brodhead, WI) and mixed with calcium hydroxide at a rate of 50 g $Ca(OH)_2$ (kg of crop DM)$^{-1}$ for approximately 10 min to ensure thorough mixing. The other crops were harvested into trucks and were not exposed to potential particle size reduction by mixing. The crops were subsequently packed into plastic silage bags and stored anaerobically for more than 60 d.

Cows and Diets

One hundred twenty-eight lactating Holstein cows, averaging 70 ± 25 DIM and 46 ± 11 kg of milk d^{-1} at trial initiation, were stratified by parity, DIM, and level of production and assigned to 16 pens of 8 cows each in the University of Wisconsin sand-bedded freestall barn (Emmons Blaine Dairy Research Center, Arlington, WI). Pens were randomly assigned to 1 of 4 treatments in a completely randomized design with a covariate adjustment. The study was performed over 11 wk, including a 2-wk covariate period, 1-wk transition to experimental diet, and 8 wk of feeding the experimental diets. Experimental diets were designed to contain (DM basis) corn silage (41.6%), alfalfa silage (19.4%), high-moisture shelled corn (14.8%), whole cottonseed (3.3%), and concentrate mixture and ground limestone (20.6%), where treatments varied by source of corn silage and were substituted on an equivalent OM amounts of the different corn silages. The 4 diets (Table 2) were a negative control (WPCS), a positive control (BMR), calcium hydroxide–treated corn silage (**TRTCS**), and toplage (**TPL**). The TPL diet contained 347 g (DM) of toplage and 76 g (DM) of calcium hydroxide–treated stalklage (1 kg of TMR DM)$^{-1}$, a ratio similar to the harvested mass ratio. The TPL ration was formulated not for optimal performance but rather to compare the effects on fiber digestibility due to treatment of the lower portions of the corn stalk, although we recognize that a substantial benefit of a fractionated crop is the ability to further optimize the ration beyond what the whole plant yields in the field. Feeding commenced on Dec 4, 2014, and took place when average ambient temperatures were below freezing. The covariate period diet was similar to the treatment diets using the herd nonexperimental corn silage instead of treatment corn silages. Ground limestone was added to all diets to meet the nutrient requirements for calcium, except for TRTCS, which had an excess of calcium due to treatment (NRC, 2001). In Table 2, the TMR composition presented represents ingredients as they were actually