J. Dairy Sci. 101:1–7
https://doi.org/10.3168/jds.2017-14317

Technical note: A comparison of alkali treatment methods to improve neutral detergent fiber digestibility of corn stover

D. M. Donnelly,* L. C. de Resende,*† D. E. Cook,* R. H. Atalla,‡ and D. K. Combs*[1]
*Department of Dairy Science, University of Wisconsin, Madison 53706
†Department of Veterinary Medicine, Federal University of Lavras, Lavras, Minas Gerais, Brazil 37200
‡Cellulose Sciences International, Madison, WI 53719

ABSTRACT

The objective of this study was to compare neutral detergent fiber (NDF) digestibility of corn stover that had been treated by 2 alkali treatment methods. Two experiments were conducted to test a sodium hydroxide (NaOH) treatment method that uses an ethanol/water co-solvent (NaOH/ethanol-H_2O, United States Patent No. 20140220228) and a calcium hydroxide (CaOH) treatment method, which uses water as a solvent (CaOH/H_2O). An in situ trial was conducted to compare NDF digestion kinetics between NaOH/ethanol-H_2O-treated stover, CaOH/H_2O-treated stover, untreated corn stover, and soy hulls. The digestion rate of potentially digestible NDF (k_d) of NaOH/ethanol-H_2O-treated corn stover (5.36%/h) was higher than CaOH/H_2O-treated stover (2.27%/h), or untreated corn stover (1.76%/h) and similar to the k_d of soy hulls (4.93%/h). The indigestible NDF (iNDF) fraction of untreated corn stover (35.1% of NDF) was reduced by CaOH/H_2O treatment (27.3% of NDF) and by NaOH/ethanol-H_2O treatment (2.8% of NDF). The iNDF fraction in soy hulls (3.6% of NDF) was similar to iNDF of NaOH/ethanol-H_2O-treated stover. An in vivo digestibility trial was also conducted to compare fiber digestibility of diets supplemented with untreated corn stover, NaOH/ethanol-H_2O-treated corn stover, or soy hulls. Total-tract apparent dry matter (DM) and NDF digestibility were measured with 8 lactating Holstein cows in a replicated 4 × 4 Latin square with four 21-d periods. Apparent DM digestibility (DMD) was improved when supplemental soy hulls were added to the base diet (60.0% DMD) compared with the base diet with no supplemental fiber (57.7% DMD). Apparent DM digestibility was reduced when diets were supplemented with untreated stover (52.4%). Dry matter digestibility of NaOH/ethanol-H_2O-treated stover was similar (54.8% DMD) to all other treatments. Digestibility of NDF was lowest when cows were fed the diet with supplemented untreated stover (35.5% of NDF), and improved when soy hulls (40.6% of NDF) or NaOH/ethanol-H_2O-treated stover (43.8% of NDF) were added to the diets. The NaOH/ethanol-H_2O treatment process improves the DM and NDF digestibility of corn stover to values similar to those of soy hulls.
Key words: alkali treatment, soy hull, dairy cattle

Technical Note

Crop residues can be treated with alkali compounds such as sodium hydroxide (NaOH), ammonia, or calcium hydroxide (CaOH) to improve fiber digestibility and animal performance (Wanapat et al., 1985; Watson et al., 2015). Alkali treatment of corn stover results in reduction of the levels of hemicellulose and lignin by dissolving them, as well as reducing the strength of hydrogen bonds between cellulose molecules, causing the cellulose to swell (Jackson, 1977). Calcium oxide is also used as a treatment for crop residues due to it being readily available and safer to handle than sodium hydroxide (Watson et al., 2015). In research cited in a comprehensive literature review on swelling agents in cotton, the absorption of alkali into the cellulose structure increases when an ethanol-water co-solvent is used as compared with using only water as a solvent (Warwicker et al., 1966). The use of an ethanol-water co-solvent also results in higher proportions of the hemicellulose being retained in the treated fiber rather than being solubilized and lost, as would be the case when only water is used (Kim et al., 2009). Alkali treatments with ethanol-water co-solvents are widely used in the wood and textile industries, but little information has been published regarding this treatment method on fibrous crop residues for animal feed.

Two experiments were conducted to evaluate a sodium hydroxide and ethanol-water co-solvent treatment method on corn residue: (1) an in situ study compared rate and extent of NDF digestion in corn stover that

Received December 19, 2017.
Accepted March 23, 2018.
[1] Corresponding author: dkcombs@wisc.edu

was treated with CaOH/H_2O or with NaOH/ethanol-H_2O; (2) an in vivo trial evaluated total-tract DM digestibility and NDF digestibility of diets containing supplemental untreated corn stover, NaOH/ethanol-H_2O-treated stover, or soy hulls. Soy hulls were used as a positive control in these experiments due to their high concentration of cellulose as well as low concentration of ferulic acid, a phenolic monomer that promotes crosslinking between hemicellulose and lignin (Garleb et al., 1988).

The hypothesis for the in situ study was that the NaOH/ethanol-H_2O treatment process would improve NDF digestibility of corn stover to a greater degree than the CaOH-H_2O treatment process. For the in vivo trial, the DM and NDF digestibility of diets supplemented with stover treated with NaOH/ethanol-H_2O was hypothesized to increase relative to diets supplemented with untreated stover.

The CaOH/H_2O-treated corn stover was prepared by adding water to the stover to adjust the DM to 50% and then adding 70 g of CaOH per 1 kg of corn stover, similar to the procedure described in Peterson et al. (2014). For the in situ study, 1 kg of DM of corn stover was treated and sealed in a plastic bag with a vacuum sealer (MiniPack America, Orange, CA) and placed on a laboratory bench for 7 d before further processing. Corn stover used for these studies was baled after grain harvest. The material consisted primarily of stalk and leaf material with minimal cobs. The corn stover was ground to approximately 8 to 19 mm in length before treating.

The NaOH/ethanol-H_2O-treated corn stover was prepared at ambient temperature with sodium hydroxide and ethanol co-solvent following the procedure described in US patent number 20140220228 (Atalla, 2014). The corn stover used for both the in situ incubation and the feeding study were treated with a 1.5 *M* solution of NaOH for 15 min in a solution of 75% ethanol-25% water co-solvent. The NaOH was then neutralized by converting it into a sodium salt for removal from the solution. The material was then allowed to dry. The NaOH/ethanol-H_2O-treated stover for the in vivo trial was prepared at the US Forest Products Laboratory (Madison, WI). Approximately 1,000 kg of corn stover was ground to approximately 8 to 19 mm in length and treated with NaOH/ethanol-H_2O as described above.

The in situ study was conducted with 2 rumen-fistulated Holstein dairy cows fed a diet consisting of approximately 45% alfalfa silage, 27% corn silage, 11% alfalfa hay, 6% straw, and 11% concentrate (DM basis). The diet had an NDF content of approximately 46.1%. The in situ study compared rates of degradation of potentially digestible NDF ($\boldsymbol{k_d}$) and the proportion of indigestible NDF (iNDF240, determined by in situ incubation for 240 h) in untreated stover, CaOH/H_2O-treated corn stover, NaOH/ethanol-H_2O-treated corn stover, and soy hulls. All samples were ground to 2 mm through a Wiley mill, then 0.5 g was weighed into Ankom F57 fiber filter bags (Ankom Technology, Macedon, NY). Duplicate samples were placed in the rumens of 2 cows for 0, 12, 24, 30, 36, 42, 48, 96, 120, and 240 h, with bags placed in reverse chronological order. The in situ bags were put into weighted laundry bags and the laundry bags were placed into the liquid phase of the rumen directly below the cannula. Bags were all removed at the same time and placed in ice before being rinsed in a clothes washer with cold water for two 12-min rinse cycles. After rinsing, bags were placed into a forced-air oven for 48 h at 60°C and then analyzed for NDF using the Ankom 200 fiber analyzer (Ankom Technology). The NDF solution contained sodium sulfite and 4 mL of α-amylase (Ferreira and Mertens, 2007). The samples were then rinsed with acetone twice, air-dried in a hood, and placed in a forced-air oven overnight at 105°C. Samples were then weighed and NDF residues were calculated. Following completion, total-tract NDF digestibility (**TTNDFD**) was estimated using the procedure described in Lopes et al. (2015).

The experimental design of the feeding trial was a replicated 4 × 4 Latin square design. Eight lactating multiparous Holstein dairy cows (199 ± 15 DIM; mean ± SD) averaging 717.1 ± 51.3 (mean ± SD) kg of BW were fed with treatments randomly assigned for each 21-d period. The cows were housed in tiestalls in the Dairy Cattle Center at the University of Wisconsin–Madison. Cattle were fed for ad libitum intake once daily after the morning milking, with daily offerings and refusals weighed and recorded and with water provided ad libitum. Animals were cared for according to the guidelines of the University of Wisconsin–Madison Institutional Animal Care and Use Committee.

A base diet was fed to all cows, and supplemental soy hulls, NaOH/ethanol-H_2O-treated stover, or untreated stover was added at 8.7% of DM afterward. Supplemented fiber was hand-mixed into the base TMR after the feed had been deposited in front of the animals each morning (0800 h). Samples of all feed ingredients were taken at the start of each week to take into account any changes in DM.

All diet ingredients and orts were collected during d 16 to 19 of each period. Feed ingredients were composited at the end of each period and stored at −20°C until completion of the trial. Samples were then dried at 60°C for 48 h in a forced-air oven to obtain DM values. Samples were ground to 1 mm through a Wiley mill before analysis (Wiley mill, Arthur H. Thomas, Philadelphia, PA). Alfalfa and corn silage, soy hulls,