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

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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-H₂O, United States Patent No. 20140220228) and a calcium hydroxide (CaOH) treatment method, which uses water as a solvent (CaOH/H₂O). An in situ trial was conducted to compare NDF digestion kinetics between NaOH/ethanol-H₂O-treated stover, CaOH/H₂O-treated stover, untreated corn stover, and soy hulls. The digestion rate of potentially digestible NDF (k_d) of NaOH/ethanol-H₂O-treated corn stover (5.36%/h) was higher than CaOH/H₂O-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/H₂O treatment (27.3% of NDF) and by NaOH/ethanol-H₂O treatment (2.8% of NDF). The iNDF fraction in soy hulls (3.6% of NDF) was similar to iNDF of NaOH/ethanol-H₂O-treated stover. An in vivo digestibility trial was also conducted to compare fiber digestibility of diets supplemented with untreated corn stover, NaOH/ethanol-H₂O-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 mat-

ter digestibility of NaOH/ethanol-H₂O-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-H₂O-treated stover (43.8% of NDF) were added to the diets. The NaOH/ethanol-H₂O 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

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rate and extent of NDF digestion in corn stover that was treated with CaOH/H₂O or with NaOH/ethanol-H₂O; (2) an in vivo trial evaluated total-tract DM digestibility and NDF digestibility of diets containing supplemental untreated corn stover, NaOH/ethanol-H₂O-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-H₂O treatment process would improve NDF digestibility of corn stover to a greater degree than the CaOH-H₂O treatment process. For the in vivo trial, the DM and NDF digestibility of diets supplemented with stover treated with NaOH/ethanol-H₂O was hypothesized to increase relative to diets supplemented with untreated stover.

The CaOH/H₂O-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-H₂O-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-H₂O-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-H₂O 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 (k_d) and the proportion

of indigestible NDF (iNDF240, determined by in situ incubation for 240 h) in untreated stover, CaOH/H₂O-treated corn stover, NaOH/ethanol-H₂O-treated corn stover, and soy hulls. All samples were ground to 2 mm through a Wiley mill (Arthur H. Thomas, Philadelphia, PA), and 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-H₂O-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 (Arthur H. Thomas). Alfalfa

and corn silage, soy hulls, untreated corn stover, and NaOH/ethanol-H₂O-treated corn stover were analyzed for DM, OM (method 942.05, AOAC International, 2016), CP (method 990.03, AOAC International, 2016), and NDF using Ankom F57 fiber filter bags, sodium sulfite, and α -amylase in an Ankom 200 fiber analyzer (Ankom Technology) as described in Ferreira and Mertens (2007), with the exception that we used 4 mL of α -amylase instead of 5 mL. Fecal samples were collected to cover a 24-h period during d 18 to 21 of each period for digestibility determination. Indigestible NDF (iNDF) was used as an internal digestibility marker. The iNDF was determined as the undigested NDF residue after 240 h of in situ incubation in 2 fistulated lactating Holstein dairy cows. Values of NDF and iNDF were corrected for ash content. The TMR feed composition data were derived from the analysis of each of the individual diet ingredients and calculated based on their contribution to the ration on a DM basis.

Cattle were milked twice daily at approximately 0400 and 1600 h. Daily milk weights were recorded for each cow. Milk samples were taken from a.m. and p.m. milkings during d 16 and 17 of each period and analyzed for butterfat, protein, lactose, SNF, SCC, and MUN via infrared spectrophotometry (AgSource Milk Analysis Laboratory, Menomonie, WI) using a Foss FT6000 near infrared spectrophotometer (Foss Electric, Hillerød, Denmark). Average daily protein and butter fat yields were calculated from these data for each period. Yields of 4% FCM and ECM were calculated according to NRC (2001) equations.

During the in vivo trial, an in situ incubation was conducted on the untreated stover and NaOH/ethanol-H₂O-treated stover used in the trial, as well as corn stover treated with NaOH/ethanol-H₂O for 1 h instead of 15 min. Samples were handled similarly to the in situ samples described above with the exception that these samples were ground to 1 mm, triplicated in each of the 2 cows, and were incubated for 0, 24, 30, 48,

and 240 h. These results were also reported on an OM basis (method 942.05, AOAC International, 2016). The results were analyzed using the TTNDFD and k_d predictions as described in Lopes et al. (2015).

In the in situ trial, the fraction of iNDF and the rate of potentially digestible NDF (pdNDF) degradation between forages were compared using ANOVA in the PROC MIXED procedure of SAS, version 9.3 (SAS Institute Inc., Cary, NC) as a randomized design with cows as replicates. Least square treatment means were compared by PDIF. The rate of pdNDF degradation was determined using 8 time points (12, 24, 30, 36, 42, 48, 96, and 120 h). Natural logs of the pdNDF residue percentages were calculated. A log-residue value less than -3 was discarded as an invalid result (Bender et al., 2016). A linear regression based on the natural log residual values versus time was then fit to the data, and k_d was determined as the slope of the regression.

Data analysis for the in vivo trial was conducted using the PROC MIXED procedure of SAS version 9.3 (SAS Institute Inc.). Random effects were set as cow within block and period, with treatment set as the fixed effect. Statistical significance was determined at $P < 0.05$, with tendency being between $0.05 \leq P \leq 0.10$. A Tukey test was used to compare treatment means.

Results of the in situ digestibility trial indicated that the NaOH/ethanol-H₂O-treated stover contained less iNDF than the CaOH/H₂O-treated corn stover or the untreated corn stover (2.8, 27.3, and 35.1% of NDF, respectively, $P < 0.01$; Table 1). Soy hulls were found to have similar iNDF concentrations as the NaOH/ethanol-H₂O-treated stover (3.6 and 2.8% of NDF, respectively, $P = 0.26$).

The digestion rate of pdNDF of the NaOH/ethanol-H₂O-treated corn stover (5.36%/h) was higher than the CaOH-treated corn stover (2.27%/h, $P < 0.01$), and untreated corn stover (1.76%/h, $P < 0.01$). The k_d of the pdNDF of the NaOH/ethanol-H₂O-treated stover was similar to that of the soy hulls (4.93%/h, P

Table 1. In situ incubation results

Item	Untreated stover	Soy hulls	CaOH/H ₂ O stover	NaOH/ethanol-H ₂ O stover	SEM	<i>P</i> -value ¹
k_d , ² %/h	1.76 ^b	4.93 ^a	2.27 ^b	5.36 ^a	0.51	<0.01
NDF, ³ % of DM	70.3 ^{ab}	56.2 ^c	65.5 ^b	74.9 ^a	1.19	<0.01
iNDF, ⁴ % of NDF	35.1 ^c	3.6 ^a	27.3 ^b	2.8 ^a	0.49	<0.01
TTNDFD, ⁵ % of NDF	30.2	72.7	40.7	84.6	—	—

^{a-c}Means within a row with different superscripts differ ($P < 0.05$).

¹Represents the *P*-value from ANOVA results.

²Rate of digestion of potentially digestible NDF, as determined by slope of linear regression of natural log values over time.

³SEM for soy hulls was 1.03; SEM for other feedstuffs presented in table.

⁴Indigestible NDF determined by in situ incubation for 240 h.

⁵Estimate of total-tract NDF digestibility (Lopes et al., 2015).

Table 2. Nutrient composition of fiber sources used in the feeding trial

Variable	Corn silage	Alfalfa silage	Untreated stover	NaOH/ethanol-H ₂ O stover	Soy hulls
DM, % as fed	40.5	50.8	88.4	90.0	88.9
OM, % of DM	96.3	90.1	96.3	97.1	95.1
CP, % of DM	7.2	17.6	3.19	1.94	10.4
Starch, % of DM	31.7	0.57	1.05	0.53	1.28
Lignin, % of DM	2.99	7.12	6.41	5.33	2.81
Ether extract, % of DM	3.07	4.10	0.82	0.40	1.64
Ash, % of DM	3.68	9.90	3.75	2.91	4.89
NDF, ¹ % of DM	37.7	41.7	83.1	87.6	64.7
iNDF, ^{1,2} % of NDF	29.3	43.0	30.4	10.2	4.30

¹NDF and indigestible NDF (iNDF) values were calculated on an ash-free basis.

²Indigestible NDF determined by in situ incubation for 240 h, calculated on an ash-free basis.

= 0.56). From the estimates of TTNDFD, it appears numerically that the NaOH/ethanol-H₂O-treated corn stover has a digestibility similar to soy hulls (84.6 and 72.7, respectively), and higher than untreated stover and CaOH/H₂O-treated stover (30.2 and 40.7, respectively).

Chemical composition of forages and other diet fiber sources for the in vivo trial are found in Table 2. The NaOH/ethanol-H₂O-treated stover had a similar NDF content compared with that of the untreated stover, but the iNDF percentage of the NaOH/ethanol-H₂O-treated stover was much lower than that of the untreated stover. These results were not as great as those seen in the in situ study. When the NaOH/ethanol-H₂O process was scaled up to process larger volumes of corn stover, it appears that the 15 min processing time did not process to the same extent as in the previous trial. When the process was scaled up at the USDA Forest Products laboratory, fine stover particles could not be retained as they would have been in a bench top process. This could explain part of the difference.

Results from the in situ incubation with the NaOH/ethanol-H₂O-treated corn stover treated for a longer period are shown in Table 3. By soaking the stover in the NaOH/ethanol-H₂O solution for 1 h rather than

15 min, the reaction made cellulose more accessible to the microbes, allowing for this stover to have a higher TTNDFD and k_d compared with the control and the stover that was treated for 15 min. The TTNDFD of the stover treated for 1 h was similar to the TTNDFD of the soy hulls. The longer soaking also resulted in lower NDF and iNDF concentrations compared with the other treatment and the untreated corn stover (Table 3). The NDF and iNDF of the stover soaked for 1 h was similar to soy hulls (Table 3).

Ingredient and nutrient compositions of diets fed during the feeding trial are shown in Table 4. The goal was to formulate the diets such that the control diet would contain approximately 25% NDF on a DM basis. The 3 diets with supplemental fiber were formulated to contain 30% NDF on a DM basis. This was accomplished by feeding a base diet to all cows, then top dressing and manually mixing in the untreated corn stover, NaOH/ethanol-H₂O-treated stover, or soy hulls by hand at each feeding time. The fiber supplements displaced approximately 8.7% of the base diet. All diets were fed for ad libitum DMI. Orts averaged approximately 8% of the offered ration and did not differ by treatment. There was no visual indication of sorting on any of the treatment diets.

Table 3. NDF characteristics for differing corn stover treatments and soy hulls

Item	Untreated stover	NaOH/ethanol-H ₂ O stover-trial ¹	Extended processing time, NaOH/ethanol-H ₂ O stover ²	Soy hulls
NDF, % of DM	83.1 ± 0.11 ³	85.9 ± 0.46	61.2 ± 0.43	63.8 ± 0.23
iNDF, ⁴ % of NDF	34.6 ± 3.27	9.62 ± 1.57	4.53 ± 0.53	3.65 ± 0.38
TTNDFD, ⁵ % of NDF	31.0 ± 6.99	43.3 ± 7.60	71.0 ± 4.58	78.8 ± 7.13
k_d of pdNDF, ⁶ %/h	1.98 ± 0.70	2.18 ± 0.61	5.40 ± 0.99	7.45 ± 2.01

¹NaOH/ethanol-H₂O-treated stover that was used in the in vivo study (treated for 15 min).

²NaOH/ethanol-H₂O-treated corn stover treated for a longer period of time (1 h).

³Represents mean ± SD.

⁴Indigestible NDF determined by in situ incubation for 240 h, calculated on an ash-free basis.

⁵Total-tract NDF digestibility prediction (Lopes et al., 2015).

⁶Rate of digestion of potentially digestible NDF (pdNDF).

Table 4. Ingredients and chemical composition of the diets

Item	Treatment			
	Control	Soy hulls	NaOH/ethanol-H ₂ O stover	Untreated stover
Ingredient, %				
Corn silage	26.9	23.1	23.1	23.1
Alfalfa silage	34.6	28.9	28.9	28.9
NaOH/ethanol-H ₂ O-treated corn stover	—	—	8.7	—
Soy hulls	—	8.7	—	—
Untreated corn stover	—	—	—	8.7
Dried distillers grains with solubles	10.8	11.1	11.1	11.1
Corn (coarse ground)	14.5	14.8	14.8	14.8
Soybean meal (46% CP)	6.9	7.1	7.1	7.1
Corn gluten feed (18% CP)	3.5	3.6	3.6	3.6
Magnesium-potassium-sulfate ¹	0.12	0.12	0.12	0.12
Vitamin premix ²	0.16	0.17	0.17	0.17
Trace mineral salt ³	0.09	0.09	0.09	0.09
Biotin Mixer 320 ⁴	0.09	0.09	0.09	0.09
Nutrient composition				
DM, % of as fed	56.4	57.9	58.0	57.9
OM, % of DM	92.5	92.7	92.8	92.8
CP, % of DM	16.5	16.3	15.6	15.7
Starch, % of DM	20.8	20.0	19.9	20.0
NDF, % of DM	30.7	32.6	34.5	34.1
NFC, % of DM	41.1	39.7	38.8	38.9
Lignin, % of DM	3.89	3.62	3.84	3.96
Ether extract, % of DM	4.21	4.04	3.94	3.97
Ash, % of DM	7.5	7.3	7.2	7.2

¹Dynamate (11% Mg, 18% K, 22% S; The Mosaic Co., Plymouth, MN).

²Vitamin A, 1,500,000 IU/kg; vitamin D, 500,000 IU/kg; and vitamin E, 5,000 IU/kg.

³0.29% Ca, 0.5% Mg, 0.21% S, 37.5% Na, 56.3% Cl; 23 mg/kg of Co, 1,450 mg/kg of Cu, 95.2 mg/kg of I, 3.2 mg/kg of Mn, 60.4 mg/kg of Se, and 5,510 mg/kg of Zn.

⁴Biotin Mixer 320 (18.5–20% Ca, 0.71 mg/g of biotin per gram of ingredient; VitaPlus, Madison, WI).

Dry matter intake was similar among treatments and the control diet (Table 5). Dry matter digestibility (DMD) differed significantly among the treatments. The control diet and the diet supplemented with soy

hulls were similar, and both had higher DMD than for the diet with untreated stover ($P < 0.0001$). The DMD of the ration supplemented with NaOH/ethanol-H₂O-treated stover was not different from the control and

Table 5. Intake and total-tract digestibility as influenced by diets

Item	Treatment ¹				SEM	P-value ²
	Control	Soy hulls	NaOH/ethanol-H ₂ O stover	Untreated stover		
Intake						
DM, kg/d	29.1	30.3	29.6	28.7	1.17	0.28
NDF, kg	10.1	10.5	10.3	10.0	0.4	0.28
iNDF, kg	1.05	1.09	1.07	1.00	0.04	0.28
NDF, % of BW	1.39	1.44	1.40	1.40	0.08	0.24
iNDF, % of BW	0.14	0.15	0.15	0.14	0.01	0.24
Total-tract digestibility, %						
DM	57.7 ^a	60.0 ^a	54.8 ^{ab}	52.4 ^b	1.60	<0.01
OM	75.8 ^a	75.0 ^{ab}	73.9 ^b	72.1 ^c	1.03	<0.01
NDF ⁴	35.5 ^b	40.6 ^{ab}	43.8 ^a	35.3 ^b	2.20	<0.01

^{a-c}Means within a row with different superscripts differ ($P < 0.05$).

¹Diets consisted of a low-fiber control diet (25% diet DM as NDF), and treatment diets containing the control diet as well as 2.1 kg of soy hulls, NaOH/ethanol-H₂O-treated stover, or untreated corn stover.

²P-value represents the treatment effect.

³iNDF = indigestible NDF.

⁴NDF digestibility determined on an ash-free basis.

Table 6. Milk yield and composition as influenced by diets

Item	Treatment ¹				SEM	<i>P</i> -value ²
	Control	Soy hulls	NaOH/ethanol-H ₂ O stover	Untreated stover		
Production, kg/d						
Milk	28.0	30.7	27.9	29.9	3.30	0.35
ECM ³	32.2	33.6	30.5	33.6	3.50	0.49
4% FCM ⁴	29.9	31.1	28.2	31.4	3.36	0.49
Component, %						
Fat	4.40	4.05	4.16	4.36	0.27	0.39
Protein	3.40	3.31	3.39	3.35	0.12	0.25
Lactose	4.59	4.71	4.72	4.69	0.11	0.32
SNF	8.89	8.91	8.98	8.92	0.14	0.79
Yield, kg/d						
Fat	1.25	1.25	1.14	1.29	0.15	0.50
Protein	0.95	1.02	0.93	0.99	0.10	0.47
MUN, mg/dL	12.3	11.8	11.8	11.7	0.89	0.85

¹Diets consisted of a low-fiber control diet (25% diet DM as NDF), and treatment diets containing the control diet as well as 2.1 kg of soy hulls, NaOH/ethanol-H₂O-treated stover, or untreated corn stover.

²*P*-value represents the treatment effect.

³ECM = [0.327 × milk (kg/d)] + [12.95 × fat (kg/d)] + [7.2 × protein (kg/d)].

⁴4% FCM = 0.4 × milk (kg/d) + [15 × fat (kg/d)].

soy hull rations or the untreated stover ration ($P > 0.05$). The NaOH/ethanol-H₂O-treated stover ration had significantly higher NDF digestibility, and the soy hulls ration tended to have higher NDF digestibility (43.8 and 40.6%, respectively) compared with the diet supplemented with untreated stover (35.3%; $P < 0.01$, $P = 0.10$, respectively). The NDF digestibility of the NaOH/ethanol-H₂O-treated stover diet was similar to the soy hull diet, and significantly higher than the control diet ($P < 0.01$). The control and untreated stover diets were similar in NDF digestibility ($P > 0.05$).

Milk production across all treatments was similar (Table 6). Yields of 4% FCM and ECM were also similar among all treatments. Milk fat percentage and milk fat yield were similar among all treatment diets ($P > 0.05$; Table 6). Milk protein percentage and yield, lactose and SNF percentages, and MUN concentrations were also similar among treatment groups ($P > 0.05$; Table 6). We did not expect to see differences in milk yield because the cows selected for this study were in late stages of lactation. Production and intake was measured to verify that no major negative effects occurred as a result of consuming the NaOH/ethanol-H₂O-treated stover and that intake and palatability did not differ due to diet. To assess more accurately how changes in fiber digestibility of stover due to the NaOH/ethanol treatment affect milk production, a larger number of cows earlier stages of lactation would be needed, which may be done in the near future.

Supplementing the base diet with the treated stover had no significant effect on DMI, milk production and

components, or the amount of fiber that these cattle ingested. Dry matter digestibility and OM digestibility were decreased when untreated corn stover was supplemented into the base ration ($P < 0.01$). Adding NaOH/ethanol-H₂O-treated stover to the base diet significantly increased in vivo NDF digestibility compared with the base diet and the base diet supplemented with untreated stover ($P < 0.01$). Intakes of NDF and iNDF were similar, both in kilograms consumed and as a percentage of BW ($P > 0.05$). Singh and Jackson (1971) also found an increase in OM digestibility when wheat straw was treated with an alkali treatment compared with the untreated straw.

The NaOH/ethanol-H₂O process increased the NDF digestibility of corn stover more than that of the CaOH/H₂O treatment. Results from the in vivo study indicate no major issues with voluntary DMI. Preliminary results from the stover treated with NaOH/ethanol-H₂O for 1 h versus the 15-min treatment indicate that fiber digestibility increases with a longer soaking time. This method would allow residue that otherwise would be left on the field and incorporated into soil OM to become a fiber source that would have a digestibility similar to that of soy hulls.

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