Digestibility of Crop Residues After Chemical Treatment and Anaerobic Storage

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Summary

Two experiments were conducted to evaluate factors affecting crop residue digestibility. Corn stover, corn cobs, and wheat straw were alkaline treated at low (35%) or high (50%) moisture and then anaerobically stored at 30°C or 40°C. Chemical treatment increased in vitro *DM digestibility of all residues by 14 to 21 percentage units (35% to 62% improvement). Samples stored at 50% DM and 40°C were most digestible. Cobs were inherently more digestible than straw or corn stalks. Percentage of total improvement in DM digestibility by optimizing DM, ambient temperature, and chemical treatment was: stalks, 43%; wheat straw, 38%;, and cobs, 34%. Digestibility of low quality crop residues can be improved markedly by chemical treatment.*

Introduction

Agricultural crop residues typically are used as roughage or bedding for cattle because of their inherent poor digestibility. Many studies have shown that digestibility of forages and crop residues can be improved by treatment with sodium hydroxide, calcium oxide, or a blend of the two. Historically, the improvements in digestibility from calcium oxide have been moderate. Calcium oxide compared to sodium hydroxide, however, is easier to handle and presents lesser human health risks. Therefore, the objective of this study was to determine the optimum treatment combinations for improving DM and fiber digestibility of different crop residues for eventual on-farm treatment options.

Procedure

Experiment 1

The first experiment was designed as a 3x4x2 factorial with 4 replications. Treatments included: three crop residues (ground stalks, corn cobs, and wheat straw), four chemical treatments (5% CaO, 4% CaO +1% NaOH, and 3% CaO +2% NaOH plus a control stored anaerobicaly), and moisture content (35% and 50% DM). The CaO was standard quicklime (Mississippi Lime Company, Kansas City, Mo.). The CaO and NaOH (pellets) were solubilized in water to form concentrated caustic solutions, which then were applied to residues. Chemical treatments were applied to forage on a DM basis, along with water, to the targeted DM level. Samples were mixed in a batch mixer and sealed using a food grade vacuum bagger. Bags were stored anaerobically at room temperature and allowed to react for 30 days. Bags were then opened and sampled. Samples were freeze dried and ground to pass through a 1-mm screen. Samples were assayed for *in vitro* DM digestibility (IVDMD). Inoculum for IVDMD was obtained by collecting a mixture of rumen fluid (strained through four layers of cheesecloth) from two steers consuming a 30% concentrate–70% roughage diet. Inoculum was mixed with McDougall's buffer at a 1:1 ratio along with 1 gram of urea/L of rumen fluid. A 0.5 gram sample was added to a 200 mL test tube, and 50 mL of inoculum was added. Test tubes were placed in a water bath at 39°C and allowed to ferment for 48 hours. Fermentation was ended by adding 6 mL of 20% HCl per test tube, along with 2 ml of 5% pepsin solution. Tubes were placed back in the water bath for an additional 24 hours. Residue was filtered, dried at 100°C, and weighed to determine IVDMD.

Experiment 2

A second experiment was conducted to evaluate the effects of temperature and storage time on digestibility. The experiment was designed as a 2x3x2x3 factorial with 3 replications. Treatments included two chemical treatments (5% CaO, and 3% CaO +2% NaOH), three crop residues (ground stalks, corn cobs, and wheat straw), two temperatures (40°C or ambient temperature), and three storage times (7, 14, and 28 days). Water was added during treatment to adjust all samples to 60% DM. Effects of temperature were applied using an incubator set at 40°C. All other procedures (application of chemical treatment and analysis) were the same as Experiment 1.

Statistical Analysis

Data were analyzed using the MIXED procedure of SAS (SAS Institute, Cary, N.C.). The effects of treatment and all interactions were analyzed and separated using the pDiff option.

Results

Experiment 1

Data are summarized in Table 1. The three-way interaction between crop residue type, treatment, and DM was significant. All main effects were significant. Dry matter digestibility was greatest for cobs, intermediate with straw, and least with stalks. Chemical treatment was effective in improving IVDMD ($P < 0.001$). Dry matter digestibility was greater for treatments containing NaOH, compared with CaO alone. Dry matter digestibility was improved for 50% compared to 35% DM. The reason this occurred is unclear. At 50% DM, 3% CaO + 2% NaOH relative to CaO improved IVDMD 14.5% and 10% for

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corn cobs and wheat straw, respectively; however, this increase was not observed for stalks.

Experiment 2

We hypothesized that temperature may increase the rate and extent of the chemical reaction. Generally, the rate of most chemical reactions doubles with every 10°C increase in temperature. A higher temperature may also better reflect the environment inside a bunker or ag-bag, as the heat resulting from the exothermic reaction of chemical treatment is retained. Length of anaerobic storage did not affect digestibility, suggesting that extent of digestibility was not improved by anaerobically storing treated residues for more than seven days (Table 2). Temperature was effective in increasing digestibility by approximately 1 percentage unit. Similar to Experiment 1, the difference between 5% CaO and 3% CaO + 2% NaOH was significant ($P < 0.001$) and revealed an approximate 5 percentage unit improvement for digestibility when NaOH was used. The relative ranking in crop residue digestibility was similar to that observed in Experiment 1. The conclusion from this experiment is that on-farm chemical treatment of crop residues could be completed fairly quickly. Regression analysis showed increases in IVDMD for all chemical treatments relative to control. Bagging at 50% DM appears to be an optimum for extent of IVDMD. Using 5% CaO increased overall IVDMD by 11 percentage units compared to control. The difference in IVDMD between 4% CaO + 1% NaOH and 3% CaO + 2% NaOH was less than 1 percentage unit. The use of 3% CaO +2% NaOH significantly increased digestibility almost 15 percentage units, relative to control. Addition of 3% CaO + 2% NaOH, compared to 5% CaO, increased digestibility an additional 4 percentage units. Whether this difference between NaOH and CaO would impact performance has yet to be determined.

Table 1. Simple effects of chemical treatment, crop residue, and DM on IVDMD[1] in Experiment 1.

Item	Control	5% CaO	4% CaO 1% NaOH	3% CaO 2% NaOH
35% DM				
Cobs	40.37[a]	50.01[c]	54.67[b]	48.70[c]
Straw	36.52[a]	50.14[b]	50.94[b]	52.01[b]
Stalks	31.06[a]	41.99[b]	42.94[b]	41.09[b]
50% DM				
Cobs	42.46[a]	54.77[b]	55.36[b]	62.79[c]
Straw	33.38[a]	50.18[b]	51.59[b]	54.61[c]
Stalks	27.17[a]	39.99[b]	41.53[b]	40.31[b]

[abc]Within a row, values lacking common superscripts differ ($P < 0.05$).
[1]*In vitro* DM digestibility.

Table 2. Simple effects of chemical treatment, crop residue, and DM on IVDMD in Experiment 2.

Item	5% CaO	3% CaO 2% NaOH
30°C		
Cobs	44.3[e]	50.0[b]
Straw	43.2[e]	46.1[d]
Stalks	40.7[f]	43.3[e]
40°C		
Cobs	48.5[c]	51.7[a]
Straw	43.9[e]	48.5[c]
Stalks	37.8[g]	43.3[e]

[abcdefg]Values lacking common superscripts differ ($P < 0.05$).

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