EFFECT OF ALKALINE HYDROGEN PEROXIDE TREATMENT OF RICE STRAW ON IN SACCO RUMINAL DIGESTIBILITY

K. H. Myung and J. J. Kennelly*
Chonnam National University, Kwangju 500-757, Korea,
*University of Alberta, Edmonton, Alberta, Canada T6G 2P5

Introduction

A variety of chemical treatments have been applied to straw in an effort to increase the susceptibility of ligno-cellulosic substances to digestion by rumen microbes. Alkali and the ammonia (NH_3) treatments have shown the most promising results. In general, NaOH treatment results in greater improvement in digestibility of straw and animal performance than NH_3 treatment (Males, 1987). Treatment of ligno-cellulosic materials such as wheat straw and aspen with alkaline solutions of hydrogen peroxide (AHP) significantly increased degradability of plant cell wall constituents in the rumen (Kerly et al., 1985). One disadvantage of AHP treatment was a loss of 50% of hemicelluloses when pH was not regulated during treatment. However, losses of hemicellulose was greatly reduced when the pH of the AHP reaction was maintained alkaline at pH 11.5.

This research was conducted to evaluate the efficacy of AHP, NaOH or NH_3 treatment of rice straw for enhancing in sacco ruminal digestibility of dry matter and fiber components.

Materials and Methods

Three non-lactating ruminally cannulated Holstein cows (average weight 769 kg) were fed a diet with a forage to concentrate ratio (DM basis) of 90:10. Animals were fed twice daily (07:30 and 17:00 h) in equal portions.

Rice straw was chopped (5 cm length) and chemically treated with NaOH, NH_3 or AHP while untreated rice straw was used as a control. For AHP treatment, the straw was soaked in a solution of H_2O_2 (1% w/v), adjusted to pH 11.5 with 50% NaOH solution (w/w), for 5.5 h with stirring at ambient temperature. While the reaction was running, the reaction pH was kept at 11.5±3.0 by adding concentrated HCl (Kerly et al., 1987). After the reaction, the insoluble residue was neutralized with concentrated HCl, filtered and washed with distilled water until the filtrate was pH < 8, and air-dried at 60°C for 48 h. All samples were ground through a 2 mm screen and air-equlibrated for 48 h prior to analysis or placement in nylon bags for ruminal incubation. The nylon bag procedure was as described by de Boer et al. (1987). Percent disappearance of DM, NDF, ADF, and cellulose at each incubation time was calculated from the proportion remaining after incubation in the rumen. Soluble fraction, degradable fraction and long time were calculated according to Robinson and Kennelly (1988). In addition effective degradability of DM (EDDM), NDF (EDNDF), ADF (EDADF) and cellulose (EDCE) were calculated according to Ørskov and McDonald's equation (1979). Data obtained from the experiment were evaluated statistically by analysis of variance, and means were compared using the Student-Neuman-Keul's procedure.

Results and Discussion

The chemical composition of the untreated and treated rice straw is in table 1. Dry matter content of treated straws were significantly ($P < 0.05$) lower than that of untreated material, suggesting an increase in the water absorbancy. This increase in absorbancy may have resulted from the increase in the proportion of total cellulose found in low crystalline structures. The NDF and ADF contents of AHP treated straw increased ($P < 0.05$) suggesting that washing the substrate with water removed reactant chemicals and solubilized components of the straw. Cellulose contents followed trends similar to those for NDF and ADF, suggesting that most of the cellulose initially present in the straw remained after the AHP treatement. However, losses of hemicellulose and lignin with treatment supports preferential losses of hemicellulose and lignin associated with AHP treatment.

Disappearance of DM and NDF from nylon bags as a function of ruminal incubation time are

TABLE 1. CHEMICAL ANALYSES (%) OF TREATED AND UNTREATED RICE STRAW

Composition	Untreated	Treated			SE[d]
		NaOH[a]	NH_3[b]	AHP[c]	
Dry matter	93.54[e]	92.56[f]	91.24[g]	90.81[h]	0.03
Percent of dry matter					
Crude protein	6.02[e]	5.74[f]	15.12[g]	5.20[h]	0.04
Crude fat	1.72[e]	1.37[f]	1.46[f]	1.47[f]	0.05
Crude ash	11.76[e]	16.61[f]	10.80[e]	5.64[g]	0.58
Neutral detergent fiber	72.16[e]	79.24[f]	74.84[g]	83.14[h]	0.31
Acid detergent fiber	40.02[e]	48.02[f]	42.58[e]	52.23[g]	0.38
Hemicellulose	32.14[e]	31.23[f]	32.26[e]	30.91[f]	0.16
Cellulose	36.72[e]	41.49[f]	37.82[g]	46.51[h]	0.18
Acid detergent lignin	5.53[e]	5.31[ef]	5.11[f]	4.76[g]	0.07
Acid insoluble ash	3.50[e]	3.69[e]	3.41[e]	2.41[f]	0.18

[a]Soaked in a 100°C solution of 4% NaOH (w/w, as-fed basis) for 30 min and artificially dried without washing.

[b]Ammoniated with NH_3 at 4% (w/w, as-fed basis) for 72 h at 60°C.

[c]Delignified with 1% alkaline hydrogen peroxide (*AHP*) solution at ambient temperature for 5.5 h by regulating pH at 11.5.

[d]Standard error of the mean.

[e,f,g,h]Means in the same row without a common letter in their superscripts differ ($p < 0.05$).

TABLE 2. DRY MATTER AND NEUTRAL DETERGENT FIBER DISAPPEARANCE (%) FOR TREATED AND UNTREATED RICE STRAW FROM NYLON BAGS (N=3) AS A FUNCTION OF INCUBATION TIME

Incubation time (h)	Untreated	Treated			SE[d]
		NaOH[a]	NH_3[b]	AHP[c]	
Dry matter					
0	19.7[e]	15.8[f]	25.4[g]	9.3[h]	0.30
6	21.8[e]	20.2[f]	29.8[g]	13.4[h]	0.37
12	25.6[e]	29.9[f]	39.2[g]	28.4[f]	0.59
24	38.5[e]	45.2[f]	49.3[g]	45.0[f]	0.79
48	45.2[e]	64.1[f]	62.9[f]	61.4[f]	1.05
72	48.4[e]	68.5[f]	72.8[g]	81.4[h]	1.02
Neutral detergent fiber					
0	3.1[e]	1.8[f]	0.9[g]	2.5[h]	0.15
6	7.1[e]	9.4[f]	10.8[g]	7.2[h]	0.27
12	10.7[e]	20.8[f]	22.7[fg]	23.6[g]	0.60
24	25.8[e]	37.1[f]	37.5[f]	42.0[g]	0.99
48	34.9[e]	60.8[g]	54.6[f]	59.2[g]	0.74
72	43.0[e]	64.7[f]	66.7[f]	80.5[g]	1.56

[a,b,c]See table 1 for details of treatments.

[d]Standard error of the mean.

[e,f,g,h]Means in the same row without a common letter in their superscripts differ ($p < 0.05$).

summarized in table 2. DM disappearance of treated straws was higher ($P < 0.05$) than that of the untreated straws after 12 h. However, disappearance at 0 h (soluble fraction) was lower for AHP and NaOH treatments than for control samples. Ammonia treatment resulted in highest soluble DM values. At 72 h, the DM disappearance for AHP was higher ($P < 0.05$) than that for NaOH or NH_3 treatments. Disappearance of NDF was greatest for AHP treatment with intermediate values being observed for NaOH and NH_3 treatment. Acid detergent fiber and cellulose disappearance as a function of ruminal incubation time are shown in table 3. Disappearance rates for ADF and cellulose followed similar trends to those observed for DM and NDF. This may result from chemical delignification as well as a physical change in properties of the lignocellulosic material.

TABLE 3. ACID DETERGENT FIBER AND CELLULOSE DISAPPEARANCE (%) FOR TREATED AND UNTREATED RICE STRAW FROM NYLON BAGS (N=3) AS A FUNCTION OF INCUBATION TIME

Incubation time (h)	Untreated	Treated			SE[d]
		NaOH[a]	NH_3[b]	AHP[c]	
Acid detergent fiber					
0	1.2[e]	1.6[e]	0.5[f]	1.6[e]	0.17
6	5.6[e]	1.6[f]	4.6[e]	2.6[f]	0.40
12	7.3[e]	12.3[f]	15.6[g]	18.1[h]	0.51
24	23.4[e]	29.0[f]	30.7[f]	35.4[g]	0.90
48	25.9[e]	61.1[f]	49.4[g]	54.5[h]	0.72
72	35.3[e]	65.3[f]	64.7[f]	78.9[g]	0.82
Cellulose					
0	2.3[e]	0.5[h]	0.9[f]	0.7[g]	0.05
6	5.7[e]	1.6[f]	5.7[e]	1.3[f]	0.16
12	10.0[e]	12.8[f]	18.0[g]	20.3[h]	0.59
24	26.1[e]	30.2[ef]	31.8[ef]	36.7[f]	1.78
48	29.1[e]	63.0[f]	50.9[g]	57.3[h]	0.88
72	35.4[e]	66.5[f]	67.3[f]	80.5[g]	1.44

[a,b,c]See table 1 for details of treatments.
[d]Standard error of the mean.
[e,f,g,h]Means in the same row without a common letter in their superscripts differ ($p < 0.05$).

In general, the disappearance of DM and major structural carbohydrates in rice straw was greater for AHP than for NaOH or NH_3 treatments.

The non-linear paramenters of effective degradabilities of DM, NDF, ADF and cellulose are summarized in table 4. As discussed for disappearance rate, soluble fractions of DM and cellulose were lower ($P < 0.05$) than those of untreated and/or NaOH and NH_3 treated straw. However, the degradable fractions were greatly increased ($P < 0.05$) with AHP treatment. Although discrete time lag before degradation began in the rumen was not always significant ($P < 0.05$), there was a trend to decreased lag values for AHP treated straw, suggesting a greater susceptability to microbial attack in the rumen.

Effective degradabilities of DM, NDF, ADF and cellulose calculated on the basis of 0.05/h solid outflow rate were significantly ($P < 0.05$) greater for AHP treated straw compared to untreated samples.

(Key Words: Alkaline Hydrogen Peroxide, Rice Straw, Disappearance Rate)

TABLE 4. NONLINEAR PARAMETERS AND EFFECTIVE DEGRADABILITY OF DRY MATTER (EDDM), NEUTRAL DETERGENT FIBER (EDNDF), ACID DETERGENT FIBER (EDADF) AND CELLULOSE (EDCE) FOR TREATED AND UNTREATED RICE STRAW

Parameter[a]	Untreated	Treated			SE[e]
		NaOH[b]	NH_3[c]	AHP[d]	
Dry matter					
Soluble (a) (% of total)	19.9[f]	15.9[g]	25.4[h]	9.3[i]	0.34
Degradable (b) (% of total)	29.8[f]	58.5[g]	57.7[g]	92.5[h]	3.32
Degradation rate of the degradable fraction (k) (h^{-1})	0.05[f]	0.04[g]	0.02[h]	0.02[h]	0.001
Lag (l) (h)	6.1[f]	4.1[fg]	1.9[g]	2.4[g]	0.81
EDDM	34.6[f]	40.5[g]	44.1[g]	36.4[f]	0.73
Neutral detergent fiber					
Soluble (a) (% of total)	3.1[f]	1.8[f]	0.7[h]	2.5[fg]	0.21
Degradable (b) (% of total)	46.8[f]	70.7[g]	75.6[g]	95.9[h]	3.40
Degradation rate of the degradable fraction (k) (h^{-1})	0.03[f]	0.04[g]	0.03[f]	0.02[h]	0.001
Lag (l) (h)	3.7[f]	3.1[f]	0.4[g]	2.5[f]	0.20
EDNDF	20.1[f]	31.1[h]	27.7[g]	32.4[i]	0.36
Acid detergent fiber					
Soluble (a) (% of total)	1.2[f]	1.6[f]	0.5[g]	1.6[f]	0.14
Degradable (b) (% of total)	36.6[f]	74.3[g]	84.4[h]	114.8[i]	2.80
Degradation rate of the degradable fraction (k) (h^{-1})	0.03[f]	0.03[f]	0.02[g]	0.02[g]	0.002
Lag (l) (h)	3.0[f]	8.1[g]	3.0[f]	4.0[f]	0.31
EDADF	15.6[f]	31.7[i]	24.9[g]	29.1[h]	0.35
Cellulose					
Soluble (a) (% of total)	2.3[f]	1.0[g]	0.9[g]	0.7[h]	0.04
Degradable (b) (% of total)	33.6[f]	75.6[g]	100.1[g]	106.4[g]	11.10
Degradation rate of the degradable fraction (k) (h^{-1})	0.05[f]	0.04[f]	0.02[g]	0.02[g]	0.001
Lag (k) (h)	4.5[f]	7.9[g]	1.6[h]	4.4[i]	0.34
EDCE	18.8[f]	32.4[g]	25.6[h]	30.5[g]	0.90

[a]a,h and k are non-linear parameters. l is discrete lag before degradation began. EDDM, EDNDF, EDADF and EDCE are calculated on the basis of 0.05/h solid outflow rate.
[b,c,d]See table 1 for details of treatments.
[e]Standard error of the mean.
[f,g,h,i]Means in the same row without a common letter in their superscripts differ ($p < 0.05$).

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