NUTRITIVE VALUES AND GROWTH RESPONSE OF CATTLE FED AMMONIA TREATED RICE STRAW

W. J. Maeng[1] and T. Y. Chung

College of Animal Husbandry
Kon-Kuk University, Seoul 133-701, Korea

Summary

Nutritive values and fermentation rates of rice straw treated with 3% anhydrous and 3% aqueous ammonia were evaluated both in vitro and sheep metabolism trials. Daily gain, feed efficiency and feed cost per gain were also determined with growing Holstein bulls fed anhydrous and aqueous ammonia treated rice straw.

Crude protein was increased 2.4 fold and NDF was decreased 6.5%, but ADF and cellulose were not different between untreated and ammonia treated rice straw. An average of 35.5% of total added ammonia-N retained in the rice straw and other 64.5% was not retained in the rice straw.

Ammonia treatment increased in vitro DM, NDF, ADF and cellulose digestibilities by 44.8%, 43.3%, 49.4% and 42.4%, respectively, and fermentation rates by 63.3%, 132.4%, 49.4% and 42.4%, respectively.

In sheep metabolism trials, DM digestibilities of rice straw treated with anhydrous and aqueous ammonia were increased 22% and 25%, respectively over untreated rice straw. Dry matter intakes were increased 22% and 36%, respectively, and digestible DM intakes by 48% and 70%, respectively in sheep fed anhydrous and aqueous ammonia treated rice straw over untreated rice straw. Rumen ammonia and blood urea were considerably higher in sheep fed ammonia treated rice straw than sheep fed untreated rice straw.

Daily gain of Holstein bulls was increased 20.8% and 29.9% and rice straw intakes were increased 28.4% and 44.3% in anhydrous and aqueous ammonia treated rice straw over untreated rice straw. Feed conversion was improved 9.5% and 10.3% and feed cost/gain was reduced 7.1% and 9.2% respectively in anhydrous and aqueous ammonia treated rice straw group as compared with untreated rice straw group.

(**Key Words:** Rice Straw, Anhydrous Ammonia, Aqueous Ammonia, Fermentation Rate, Feed Efficiency)

Introduction

Considerable quantities of low quality roughage or crop residues are available and comprise a large potential source of feed for ruminant animals throughout the world, but they have not been utilized well as a roughage source because of its low digestibility and low rate of digestion which limits feed consumption.

Treatment of these crop residues with ammonia can increase digestibility of dry matter by 20 to 40 percent, crude protein content by 2 to 3 fold and increase voluntary consumption by 20 to 35% (Sundstøl and Coxworth, 1984; Maeng and Kim, 1984; Zorrilla-Rio et al., 1986). The development of the ammonia treatment has been described by Sundstøl (1983/84).

Each year about 7 million tons of rice straw is produced in Korea and treatment with ammonia is one of the most attractive ways to make better use of this material (Han and Garrett, 1986).

The objectives of these studies were to determine the chemical composition, digestibility and fermentation rate of rice straw treated with anhydrous and aqueous ammonia in vitro and sheep metabolism trials. Growth response, feed efficiency and feed cost per gain were also determined with growing Holstein bulls.

Materials and Methods

The rice straw was treated with either 3% anhydrous ammonia or 1.5 and 3% aqueous ammonia on an air dry basis and stored in stacks

[1] Address reprint requests to Dr. W. J. Maeng, College of Animal Husbandry, Kon-Kuk University, Seoul 133-701, Korea

Received September 19, 1988
Accepted February 6, 1989

covered with plastic as described by Sundstøl (1983/84).

In vitro digestibility was determined by the method of Tilley and Terry (1963) using rumen inoculum prepared as described by Maeng et al. (1971). Fermentation rates were determined as the slope of regression of the natural log of residue upon incubation times from 0 to 72 hours (Maeng and Baldwin, 1976; Belyea et al., 1979).

Three yearling fistulated weathers averaging 35.2 kg body weight were used in a 3x3 latin square design and fed ad libitium untreated rice straw, 3% anhydrous ammonia treated rice straw and 3% aqueous ammonia treated rice straw. Free access to a mineral salt block and water were provided. Trials were conducted in metabolism crates with a 14 day preliminary and a 7 day collection period. Rumen samples and blood were collected at different time after feeding or the 7th day of the collection period.

Growth trial was conducted with Holstein bulls weighing average of 231 kg body weight for 90 days. Eight animals per each treatment were fed ad libitum of either untreated rice straw, 3% anhydrous ammonia treated rice straw or 3% aqueous ammonia treated rice straw. All animals also received a commercial formula concentrate feed containing 15% crude protein at the rate of 1.5% of body weight.

Samples were analyzed by the following procedures; dry matter by oven drying at 105°C for 24 hours; nitrogen by the Kjeldahl method; rumen ammonia concentration by Chaney and Marbach (1962); blood urea by digital photometer; neutral detergent fiber (NDF) and acid detergent fiber (ADF) by Goering and Van Soest (1970) and cellulose by Crampton and Maynard (1938); and volatile fatty acid (VFA) by Gas-liquid chromatography. All results were tested by standard analysis of variance procedure and Duncan's multiple range test was used to separate means (Steel and Terrie, 1980).

Results and Discussion

Chemical composition of the untreated and treated rice straw is shown in table 1. Ammonia treatment increased by crude protein 2.4 fold

TABLE 1. CHEMICAL COMPOSITION OF AMMONIA TREATED RICE STRAW[1,2] (DM Basis)

Treatment	Chemical composition (%)			
	Crude protein	N D F	A D F	Cellulose
Untreated	4.2±0.02^{A}	80.3±0.03^{a}	53.6±0.05	37.7±0.06
NH_3 treated				
3.0%	10.1±0.10^{B}	75.3±0.07^{b}	50.5±0.04	39.7±0.10
NH_4OH treated				
1.5%	9.9±0.05^{B}	76.9±0.03^{b}	51.4±0.07	37.1±0.08
3.0%	9.2±0.09^{B}	75.1±0.04^{b}	50.4±0.05	37.8±0.08

[1]Mean of triplicate ± standard error.
[2]Mean of different superscript differ significantly (^{A,B} $P<0.01$; ^{a,b} $P<0.05$).

and decreased NDF by 6.5%. ADF and cellulose were not changed by treatment with ammonia. Similar results were also reported in previous experiments with ammonia treated rice straw (Maeng and Kim, 1984; Kim et al., 1986). Crude protein content and other chemical composition were similar for the anhydrous and aqueous ammonia treated rice straw. This is in contrast with Sundstøl and Coxworth (1984) who reported that aqueous ammonia had a greater effect than anhydrous ammonia.

Of the anhydrous and aqueous ammonia-N applied during treatment of the rice straw 38.5% and 32.4% was retained at the time it was fed respectively. The amount of ammonia-N retained in the treated straw depends on the source of

TABLE 2. TOTAL NITROGEN RETAINED IN THE RICE STRAW BY AMMONIA TREATMENT

Treatment	Total NH_3-N added (%)	Total N content in straw (%)	Total NH_3-N retained (% of added)	Total NH_3-N not retained (% of added)
Untreated	–	0.67	–	–
3% NH_3 treated	2.47	1.62	38.9	61.5
3% NH_4OH treated	2.47	1.47	32.4	67.8

straw, treatment method and moisture content of straw (Hartley and Jones, 1978; Waiss et al., 1972) and in other studies 18% to 57% of added ammonia-N was retained in the straw (Buettner et al., 1982; Saenger et al., 1982; Herrern-Saldana et al., 1982).

In vitro dry matter, NDF, ADF and cellulose digestibilities were improved by 39.9%, 38.9%, 49.5% and 49.2% on the anhydrous ammonia treatment and by 47.9%, 47.6%, 38.9% and 49.5% by the aqueous ammonia treatment (table 3). Fermentation rates of DM, NDF, ADF and cellulose of untreated rice straw were 0.64, 0.51, 0.54 and 0.93%/hr (table 4). This was increased to 1.03, 1.16, 0.95 and 1.65%/hr by anhydrous ammonia and 1.06, 1.21, 0.95 and 1.66%/hr by aqueous ammonia with an average improvement of 64% in DM, 131% in NDF, 76% in ADF and 79% in cellulose compared with the untreated rice straw. Maeng and Kim (1984) also showed that ammonia treatment of rice straw considerably improved digestibilities as well as rate of digestion.

In sheep metabolism trials, dry matter digestibility was increased by 22% and 25%, intake 22% and 36% and digestible dry matter intake 48% and 76%, respectively by the anhydrous and aqueous ammonia treatment straw (table 5). Kim

TABLE 3. IN VITRO DIGESTIBILITIES OF AMMONIA TREATED RICE STRAW[1,2]

Treatment	In vitro digestibilities (%)			
	DM	NDF	ADF	Cellulose
Untreated	40.1 ± 0.8^{a}	41.4 ± 0.2^{a}	32.1 ± 0.5^{a}	50.0 ± 0^{a}
NH_3 tracted				
3.0%	56.1 ± 0.4^{c}	57.5 ± 0.8^{c}	48.0 ± 0.4^{c}	71.0 ± 0.2^{c}
NH_4OH treated				
1.5%	50.0 ± 0.8^{b}	46.8 ± 0.2^{b}	38.7 ± 0.5^{b}	59.3 ± 0.7^{b}
3.0%	59.3 ± 0.7^{d}	61.1 ± 0.4^{d}	47.9 ± 0.3^{c}	71.4 ± 0.9^{c}

[1]Mean of triplicate ± standard error.
[2]Mean of different superscript differ significantly ($P < 0.01$).

TABLE 4. FERMENTATION RATE ON AMMONIA TREATED RICE STRAW

Treatment	Fermentation rate (%/hr)			
	DM	NDF	ADF	Cellulose
Untreated	0.64	0.51	0.54	0.93
3% NH_3 treated	1.03	1.16	0.95	1.65
3% NH_4OH treated	1.06	1.21	0.95	1.66

TABLE 5. INTAKE AND DIGESTIBILITY OF AMMONIA TREATED RICE STRAW

Treatment	Untreated	3% NH_3 treated	3% NH_4OH treated
DM digestibility (%)	44.0[a]	53.5[b]	54.8[b]
Improvement (%)	100	122	125
Intake (DM)			
g/day	646[a]	785[b]	879[c]
Improvement (%)	100	122	136
Digestible DM intake			
g/day	284[a]	420[b]	482[b]
Improvement (%)	100	148	170

[a,b,c]Mean of 3 sheep without same superscript differ significantly ($P < 0.05$).

et al. (1984) also reported similar improvement in feeding value of rice straw by ammonia treatment of rice straw. Garrett et al. (1979) showed that digestion coefficients for organic matter, ADF, cellulose and energy were higher for those diet containing 72% ammonia treated rice straw compared to untreated control diet.

Rumen ammonia-N concentration in sheep fed untreated rice straw was 1.56 mg/100 ml (0.8-2.8 mg), but increased to 13.3 mg (4.3-18.7 mg) by the 3% anhydrous ammonia treatment and 9.9 mg (4.0-13.1 mg) by the 3% aqueous ammonia treatment (figure 1).

The highest blood urea-N was 15 mg/100 ml at 2 hours after feeding in sheep fed untreated rice straw, but was 21-26 mg at 3 hours after feeding ammonia treated rice straw (figure 2).

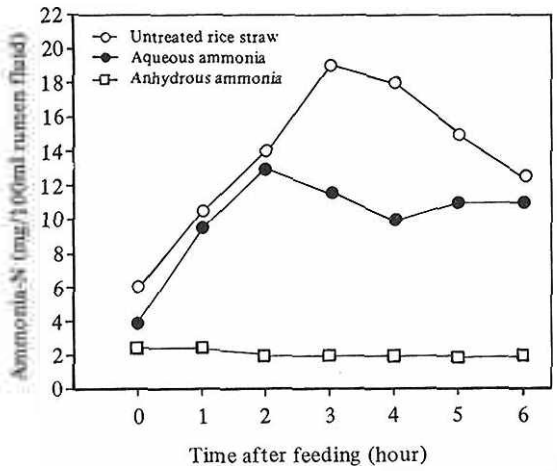

Figure 1. Rumen ammonia concentration of sheep fed untreated, anhydrous and aqueous ammonia treated rice straw.

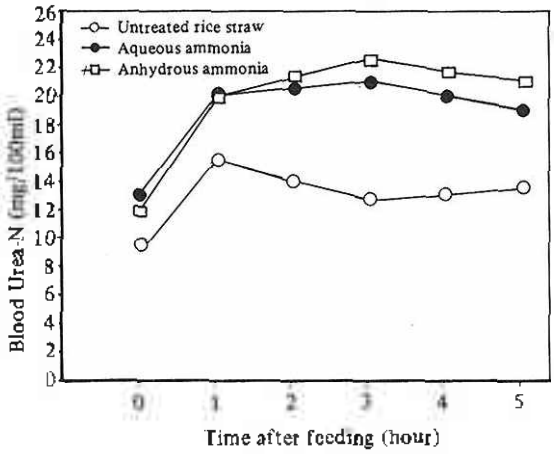

Figure 2. Blood urea-N concentration of sheep fed untreated, anhydrous and aqueous ammonia treated rice straw.

Intake and growth response of growing Holstein bulls fed ammonia treated rice straw are shown in table 6. Concentrate containing 15% crude protein were fed on the basis of 1.5% of body weight with ad libitum rice straw. Rice straw intake was increased 28.4% by the anhydrous ammonia treatment and 44.3% by the aqueous ammonia treatment. Daily gain was improved 20.8% and 29.9%, respectively for the anhydrous and aqueous ammonia treatment. Feed efficiency was improved 9.5% and 10.3%, and feed cost/gain was reduced 7.1% and 9.2%, respectively for the anhydrous and

TABLE 6. INTAKE AND GROWTH RATE OF GROWING HOLSTEIN BULL FED AMMONIA TREATED RICE STRAW

Treatment	Untreated	3% NH_3 treated	3% NH_4OH treated
No. of Animals	8	8	8
Experimental period (day)	90	90	90
Initial body weight (kg)	234.50	232.57	226.25
Final body weight (kg)	303.67	316.76	316.08
Total gain (kg)	69.17[a]	83.60[b]	89.83[b]
Daily gain (kg)	0.77[a]	0.93[b]	1.00[b]
Relative increase (%)	100	120.8	129.9
Feed Intake			
Concentrate (kg/day)	3.39	3.39	3.31
Rice straw (kg/day)	2.45[a]	3.14[b]	3.51[b]
Relative increase (%)	100	128.4	144.3

[a,b]Means without same superscript differ significantly ($P < 0.05$).

TABLE 7. FEED EFFICIENCY AND FEED COST PER GAIN OF GROWING HOLSTEIN BULLS FED AMMONIA TREATED RICE STRAW

Treatment	Untreated	3% NH_3 treated	3% NH_4OH treated
Feed conversion (kg feed D.M/kg gain)	7.68[a]	6.95[b]	6.89[b]
Improvement (%)	0	9.5	10.3
Feed cost (Won/day)	976.29[a]	1095.20[b]	1151.57[b]
Improvement (%)	0	12.2	18.0
Feed cost/gain (Won/kg gain)	1267.91[a]	1177.63[b]	1151.57[b]
Improvement (%)	0	7.1	9.2

[a,b]Means without same superscript differ significantly ($P < 0.05$).

aqueous ammonia treatment (table 7). Creek et al. (1984) also found that ammonia treated rice straw gave 27% increase in intake and 45% increase in daily live weight gain. Garett et al. (1979) also reported that steers fed diets containing 72% ammonia treated rice straw gained more weight and ate more feed and required less feed per unit of gain than those receiving the untreated control diet. Throughout these studies there were no health problems in animals fed ammonia treated rice straw.

Literature Cited

Belyes, R. L., B. K. Darcy and K. S. Jones. 1979. Rate and extent of digestion and potentially digestible cell wall of waste papers. J. Anim. Sci. 4:887-892.

Buettner, M. R., V. L. Lechtenberg, K. S. Hendrix and J. M. Hertl. 1982. Composition and digestion of ammoniated tall fescue. J. Anim. Sci. 54:173-178.

Chaney, A. L. and E. P. Marbach. 1962. Modified reagents for determination of urea and ammonia. Clinical Chemistry. 8:130-132.

Crampton, E. W. and L. A. Maynard. 1938. The relation of cellulose and lignin content to the nutritive value of animal feeds. J. Nutr. 15:32.

Creek, M. J., T. J. Barker and W. A. Hargus. 1984. The development of a new technology in an ancient land. World Animal Review. 51:12-20.

Garrett, W. N., H. G. Walker, G. O. Kohler and M. R. Hart. 1979. Response of ruminants to diets containing sodium hydroxide or ammonia treated rice straw. J. Anim. Sci. 48:92-103.

Goering, H. K. and P. J. Van Soest. 1970. Forage fiber analysis (Apparatus, reagent, procedures, and some

applications). USDA, Arg. Handbook No. 379.

Han, I. K. and W. N. Garrett. 1986. Improving the dry matter digestibility and voluntary intake of low quality roughages by various treatments. Korean J. Anim. Sci. 28(4):199-236.

Hartley, R. D. and E. C. Jones. 1978 Effect of aqueous ammonia and other alkalis on the in vitro digestibility of barley straw. J. Sci. Feed Agric. 29:92-98.

Herrera-Saldana, R., D. C. Church and R. C. Kellerns. 1982. The effect of ammonia treatment on intake and nutritive value of wheat straw. J. Anim. Sci. 54:603-608.

Kim, J. L., W. J. Maeng and M. B. Chang. 1986. The effect of anhydrous ammonia and sodium hydroxide treatment on the improvement of nutritive value of rice straw. Korean J. Anim. Sci. 28(2):86-93.

Maeng, W. J. and D. S. Kim, 1984. The effect of ammonia treatment on intake and nutritive value of rice straw. Korean J. Anim. Sci. 26(7):610-615.

Maeng, W. J., S. J. Oh and P. I. Choe. 1979. Improving nutritive value of rice straw. I. Effect of alkali treatment on the chemical composition and in vitro digestibility of indica type rice straw. Korean J. Anim. Sci. 21(4):343-349.

Maeng, W. J. and R. L. Baldwin. 1979. Dynamics of fermentation of a purified diet and microbial growth in the rumen. J. of Dairy Sci. 59(4):636-642.

Saenger, P. F., R. P. Lemenager and K. S. Hendrix. 1982. Anhydrous ammonia treatment its effects on digestibility, intake and performance of beef cattle. J. Anim. Sci. 54:491-425.

Steel, R. G. D. and J. H. Torrie. 1980. Principle and procedures of statistics (2nd Ed). McGraw-Hill Book Co., New York.

Sundstøl, F. and E. M. Coxworth. 1984. Ammonia treatment In: F. Sundstøl and E. Owen (Ed.). Straw and other fibrous by-products as fed. pp196-247. Elsevier, New York.

Sundstøl, F. 1983/84. Ammonia treatment of straw: Methods for treatment and feeding experience in Norway. Anim. Feed Sci. Technol. 10:173-187.

Tilley, J. M. S. and R. A. Terry. 1963. A two stage technique for the in vitro digestion of forage crops. J. Brit. Grassl. Sci. 18:140-111.

Waiss, A. C. Jr., J. Guggolz., G. O. Kohler, H. G. Walker Jr. and W. N. Garrett. 1972. Improving digestibility of straws for ruminant feed by aqueous ammonia. J. Anim. Sci. 35:109-112.

Zorrilla-Rios, J., G. W. Horn, W. A. Phillips and M. A. Worthington, 1986. Value of protein in ammoniated straw for growing steers. Animal Science Res. Report pp.222-228.