THE ENERGY VALUE OF RICE STRAW FOR RUMINANTS AS INFLUENCED BY TREATMENT WITH ANHYDROUS AMMONIA OR MIXING WITH ALFALFA

I. K. Han[1] and J. K. Ha
Department of Animal Science, College of Agriculture
Seoul National University, Suweon 440-744, Korea

and

W. N. Garrett and N. Hinman
Department of Animal Science, University of California
Davis, CA 95616, USA

Summary

A comparative slaughter feeding experiment with steer calves weighing 280 kg and a concurrent digestion trial with wether lambs was conducted to study the energy value of rice straw as influenced by ammonia treatment and mixing with alfalfa hay. Steers were ad libitum fed one of nine completely mixed experimental diets: basal (high concentrate); 25 or 50% of untreated rice straw (URS) or ammoniated (plastic covered bales, 4.6 % NH_3 by weight) rice straw (ARS) proportionately replacing part of the basal; a 50:50 % mixture of URS or ARS and alfalfa replacing a proportion of the basal at 25 and 50 %. Digestibility of the nine complete diets (pelleted to prevent sorting) was determined with four ad libitum fed lambs. Ammoniation increased crude protein level (from 3.6 to 10.8%) and *in vitro* dry matter digestibility of the rice straw by 15%. The improvement in DE, NEm and NEg by ammoniation of rice straw was 20, 52 and 117 %, respectively. Ammoniation of rice straw fed as 50 % of the diet improved gains over the diet containing 50 % URS, but no significant influence on animal performance was observed when rice straw was fed at the 25 % level. Each 10 % addition of URS to basal diet decreased empty body gain of steers by 116 gram per day compared with a decrease of 70 gram per day when rice straw had been ammoniated. There was no beneficial effect of ammoniation when the roughage component of the diet was a 50:50 mixture of rice straw and alfalfa. Ammoniation of straw and inclusion of alfalfa generally increased the concentration of total volatile fatty acids in rumen fluid. Ammoniation resulted in reduced concentrations of acetic and propionic acid, but increased concentration of butyric acid. Digestibility of URS was improved by mixing with alfalfa. However, alfalfa hay did not influence digestibility of ARS. Diets in which ARS replaced the basal mixture at 25 and 50 % had higher NEm and NEg values than comparable URS diets. The same pattern was observed in the straw: alfalfa mixtures, but differences between URS and ARS were significant only for the 50 % roughage diets.
(**Key Words:** Energy Value, Rice Straw, Ammoniation, Alfalfa Addition)

Introduction

Rice straw is low in lignin (3 to 5 %) and contains 52-55 % cellulose and hemicellulose, suggesting a potential source of energy for ruminants. However, since rice straw is high in silica (9-15%) and its structure is resistant to rumen microbial digestion, some chemical and physical treatments are necessary for maximum utilization as a feedstuff.

[1]Address reprint requests to Dr. I. K. Han, Animal Science Department, College of Agriculture, Seoul National University, Suweon 440-744, Korea.
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Anhydrous and aqueous ammonia have been shown to break some of the bonds between lignin and cellulose or hemicellulose in straws (Klopfenstein, 1978), and therefore, improve ration digestibility (Garrett et al., 1974; 1979; Sundstøl, 1981; 1984; Maeng and Kim, 1984) and increase voluntary feed intake (Garrett, 1974; Sundstøl, 1984; Dryden and Kempton, 1984). In a recent review, Han and Garrett (1986) indicate that ammoniation could increase feed intake by 30 % and improve *in vivo* dry matter digestibility by 20 %.

Supplementation of straws with added nutrients such as nitrogen in the form of urea or fish meal (Williams, 1984; Saadullah, 1985), sulfur (Bray and Hemsley, 1969) and other minerals (Coombe and Christian, 1969) has been effective in improving nutritional value. A beneficial effect of mixing good quality forages with straws has been reported (Choung, 1976; Devendra, 1982; Ahn et al., 1984; Brandt and Klopfenstein, 1986). Alfalfa hay, a good source of proteins and minerals, may be an ideal natural feedstuff for supplementing the nutritional inadequacies of straw.

Objectives of our experiments were to determine the influence of treating rice straw (RS) with anhydrous NH_3 or supplementation with alfalfa hay on growth, energy utilization and body composition of growing steers. Effects of ammoniation of RS on the digestibility of diets containing mixtures of alfalfa and RS were part of the investigation.

Materials and Methods

Feeding trial

Ninety calves (predominantly Herefords weighing approximately 280 kg) were assigned at random to treatments in a comparative slaughter feeding experiment. Nine diets were formulated: basal (high concentrate); 25 or 50% of untreated rice straw (URS) or ammoniated rice straw (ARS) proportionately replacing part of the basal; a 50:50 mixture of URS or ARS and alfalfa replacing a proportion of the basal at 25 % and 50 %. Rice straw (short grain variety) was obtained from one grower.

Ammoniated rice straw was prepared by the injection of anhydrous ammonia (4.6 % by weight of straw, air dry basis) into stacks of baled rice straw sealed in black polyethylene (.15 mm thick). The method was that of Kernan et al. (1977).

Ingredient and chemical composition of experimental diets are given in table 1. All the diets were fed as a completely mixed feed.

Steers were housed in individual pens (6.5 x 1.5m) with constant access to their assigned diet and water. There were 10 steers in the initial

TABLE 1. FORMULA AND NUTRIENT COMPOSITION OF EXPERIMENTAL DIETS[a]

Ingredient of composition	Basal[b]	Rice Straw				Rice straw/alfalfa			
		Untreated		Ammoniated		Untreated		Ammoniated	
		25	50	25	50	25	50	25	50
Ingredient (%);									
Rice straw		25	50	–	–	12.5	25	–	–
NH_3 rice straw	–	–	–	25	50		–	12.5	25
Alfalfa	–	–	–	–	–	12.5	25	12.5	25
Basal[b]	100	75	50	75	50	75	50	75	50
Nutrient composition (%);									
Crude protein	13.0	13.2	11.8	13.7	12.5	12.5	11.9	14.0	14.0
Ether extract	5.5	4.2	2.3	2.7	2.4	3.2	2.5	2.6	3.2
Crude ash	4.5	8.9	10.0	7.6	11.8	6.3	9.5	9.3	7.3
ADF	3.6	16.7	26.2	15.2	25.1	13.6	22.4	14.0	22.0
NDF	15.0	31.8	39.4	26.9	38.0	26.1	26.3	32.2	35.4
Hemicellulose	11.4	15.1	13.1	11.7	12.9	12.5	3.9	18.2	13.4
Cellulose	4.0	12.1	18.8	12.1	17.4	10.3	16.9	11.6	17.3
Lignin	.77	.68	.60	.71	1.49	1.73	2.12	1.0	1.85
Si	.75	2.88	5.24	2.80	5.02	1.67	3.42	1.07	2.48
Ca	.64	.74	.61	.62	.84	.83	.85	.83	.82
P	.44	.46	.32	.39	.41	.45	.35	.40	.52

[a]Vitamin A added to supply at least 2200 IU/kg.
[b]Concentrate was 5 % untreated rice straw, 73 % corn, 10 % soybean meal, 8 % molasses, 2.4 % animal fat, 0.5 % dicalcium phosphate, 0.6 % oyster shell, 0.5 % trace mineral salt (zinc, .35 %; manganese, .28 %; iron, .175 %; copper, .035 %; cobalt and iodine, .007 %; sodium chloride 93-98 %).

slaughter group. Half the experimental animals from each treatment (5) were slaughtered after 154 days; the remaining five after 161 days of feeding. Body weights were taken every 4 weeks after an overnight (3:00 pm to 8:00 am) feed and water fast.

Carcass density determined on the initial slaughter and fed steers was used to estimate body composition and thus provide the information to determine energy retention and energy utilization of the diets (Garrett and Hinman, 1969).

Rumen samples were obtained in mid-morning (after the steers had been on feed for over 100 days) by stomach tube from four steers on each diet. These samples were strained through four layers of cheesecloth and preserved with metaphosphoric acid. The preserved rumen fluid was centrifuged at 2,000 rpm for 20 min. as outlined by Erwin et al. (1961) and the volatile fatty acid determined in the supernatant by gas chromatography.

Digestion trial

Four wether lambs were used to determine the digestibility of each experimental diet. Diets were pelleted (1 cm diameter) for use in the digestion trial. Lambs were fed ad libitum in individual digestion crates. Total collection of feces using fecal bags and harnesses was made for 14 days after a 14 day preliminary period. An aliquot of feces was composited for each animal, dried in a forced-air oven at 60 °C and stored for later chemical analysis.

In vitro dry matter digestibility (IVDMD) of experimental roughages (URS, ARS, alfalfa hay) and pelleted rations were measured by the method described by Tilley and Terry (1963).

Feed and fecal samples were analyzed for proximate constituents by AOAC (1984) methods. Cell wall constituents were determined by the method of Goering and Van Soest (1970). Gross energy was by adiabatic bomb calorimetry. Trace mineral analysis of the URS, ARS and alfalfa samples was by atomic absorption.

The data collected from the steer feeding trial and the lamb digestion trial were subjected to analysis of variance. Treatment means, when the differences were significant, were compared at probability of .05 using the multiple range test (Steel and Torrie, 1960).

Results and Discussion

Nutritional characterization of URS, ARS and alfalfa hay used in the feeding and a digestion trial are in table 2. Ammoniation of rice straw increased crude protein content threefold. Other differences between URS and ARS which may be treatment related or due to sampling variation were not extensive, but the trend was for decreased ADF, NDF, hemicellulose, lignin and total ash. The IVDMD of ARS was higher than URS by almost 15 %. The most striking differences between URS and alfalfa hay were crude protein (3.6 % vs 18.8 %), cell wall constituents (67. % vs 40.7 %), lignin (4.7 % vs 8.5 %) and silica (9.9 % vs 1.0 %).

The improvement in IVDMD by ammonia treatment (15%) is less than that reported by Terashima et al. (1981) or Zorrila-Rios et al. (1985) (21 % and 28 % improvement).

Feeding trial

Rate of gain, feed intake and carcass traits

TABLE 2. NUTRIENT COMPOSITION OF UNTREATED RICE STRAW, AMMONIATED RICE STRAW AND ALFALFA HAY

Nutrients	Roughage source		
	Untreated rice straw	Ammoniated rice straw	Alfalfa hay
Crude protein (%)	3.6	10.8	18.8
Ether extract (%)	1.4	1.5	1.9
Ash (%)	16.4	14.8	7.7
NDF (%)	67.7	64.8	40.7
ADF (%)	49.2	48.4	32.3
Hemicellulose (%)	18.5	16.4	8.4
Cellulose (%)	34.6	36.5	22.4
Lignin (%)	4.7	3.5	8.5
Silica (%)	9.9	9.4	1.0
IVDMD (%)	48.9	56.1	62.4
Ca (%)	.36	.35	1.26
P (%)	.08	.10	.26
Na (%)	.06	.07	.05
K (%)	1.85	2.14	2.62
Mg (%)	.89	.79	2.42
Fe (%)	.01	.01	.03
Cu (mg/kg)	3.82	4.74	11.0
Co (mg/kg)	1.61	1.53	2.30
Zn (mg/kg)	16.2	17.0	18.1
Cr (mg/kg)	1.45	1.24	3.20
Mn (mg/kg)	510	453	33

as influenced by ammoniation of rice straw and replacing part of the RS with alfalfa are summarized in table 3. Replacing a portion of the basal diet with 50 % URS or 50 % ARS lowered ($p < .05$) gain and carcass fat content. Ammoniation of RS fed at 50 % of the diet improved gains over the diet containing 50 % URS. Ammoniation had no significant influence on animal performance when RS was fed at the 25 % level. Amount of feed required per unit empty body weight gain for steers fed RS as the only roughage was higher ($p < .05$) compared to those fed the basal diet. Ammoniation improved feed/gain ratio in steers fed either 25 % or 50 % level of RS. Diets containing 25 % RS were more ($p < .05$) efficiently converted to gain.

TABLE 3. GROWTH AND CARCASS TRAITS OF STEERS FED UNTREATED OR AMMONIATED RICE STRAW

		Rice straw				Rice straw/alfalfa				
		Untreated		Ammoniated		Untreated		Ammoniated		
Item	Basal	25	50	25	50	25	50	25	50	SE
Initial SBW[e] (kg)	284.3	283.0	281.6	280.2	281.3	280.8	283.9	280.9	285.1	4.5
Final SBW (kg)	495.5	472.6[b]	413.5[a]	471.6[b]	440.9[ab]	480.9[b]	465.7[b]	464.9[b]	455.5[b]	11.3
SBW gain (kg/d)	1.34	1.21[cd]	.84[a]	1.22[cd]	1.02[b]	1.27[d]	1.15[c]	1.17[c]	1.08[b]	.06
EBW[f] gain (kg/d)	1.27	1.12[cd]	.71[a]	1.18[cd]	.91[b]	1.24[d]	1.05[bcd]	1.14[cd]	1.01[bc]	.05
Feed (kg/d)	7.32	9.41[c]	7.67[a]	8.97[bc]	7.94[ab]	9.15[bc]	9.03[bc]	8.41[abc]	8.19[abc]	.32
Feed/gain (EBW)	5.84	8.47[bc]	11.0[d]	7.64[ab]	8.77[c]	7.40[a]	8.62[c]	7.48[a]	8.13[abc]	.23
Carcass wt (kg)	307.6	290.2[c]	241.7[a]	295.5[c]	265.1[ab]	303.0[c]	282.7[c]	291.9[c]	279.3[bc]	7.2
Carcass fat (%)	31.8	29.0[b]	22.1[a]	30.8[b]	23.8[a]	30.2[b]	29.1[b]	29.6[b]	28.6[b]	1.2

[a,b,c,d] Means in the same row with different superscripts differ ($p < .05$). Means for the basal diet are shown for comparison, but data from this treatment were not included in the statistical analysis.
[e] Shrunk body weight.
[f] Empty body weight.

Replacing the basal diet with a 50:50 mixture of URS or ARS and alfalfa at the 25 % (12.5 RS) or 50 % (25 % RS) did not have a significant influence on rate of gain although there was a pattern of less feed consumption and slightly lower gains with the ARS : alfalfa mixtures compared to the URS : alfalfa diets. Generally, diets containing URS were consumed in greater quantities than those containing ARS. Steers fed diets with 50 % roughage, especially if the roughage was all RS (either URS or ARS), consumed less ME. Within RS : alfalfa diets, there was a trend of improved feed/gain ratio by ammoniation of RS, and animals fed 25 % RS : alfalfa tended to convert feed to gain more efficiently than those fed 50 % roughage. Carcass fat content was not significantly influenced by ammoniation, however, steers fed diets containing 50 % RS (either URS or ARS) were less fat; they were also smaller when slaughtered.

Figure 1. shows the relationship between empty body weight gain (kg/day) and the level of RS in the diet. The figure clearly indicates that body weight gain decreased as the level of rice

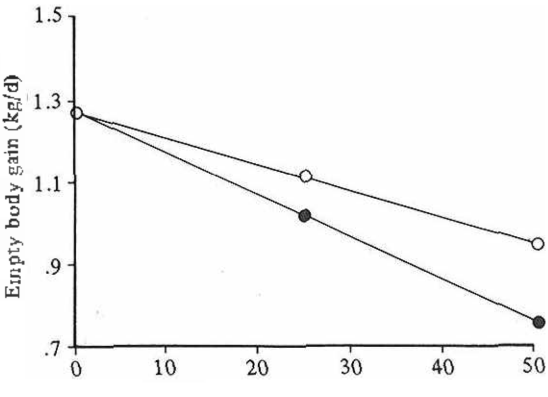

Figure 1. Empty body gain as affected by the level of untreated(●) and ammoniated (○) rice straw in complete diets.

straw increased, and the beneficial effect of ammoniation was more pronounced when rice straw was included in the diet at higher levels. Garrett et al. (1979) in comparative slaughter feeding trials with steers and sheep observed positive response in gain by NaOH and NH_3 treatment of rice straw when diets contained 72 % rice straw, but no response was obtained at inclusion levels of 36 %. The results of the current study is similar to previously cited experiments in that higher beneficial effect of straw treatment could be expected when the proportion of rice straw in the total diet increased. This aspect may explain the lack of response in empty body weight gain to ammoniation of rice straw in rice straw-alfalfa mixture groups (figure 2). The actual amount of RS (untreated or ammoniated) included in these diets were 12.5 % and 25 %. When empty body weight gains, kg/d (Y) were plotted against the proportion of rice straw in the diet (X), the regression equation was Y = 1.310 − 0.0116X (R^2 = .59) for untreated rice straw and Y = 1.296 0.00704X (R^2 = .34) for ammoniated rice straw. These results suggest that each 10 % addition of URS to the basal diet decreased empty body gain of steers by 116 g/d compared with a decrease of 70 g/d if the rice straw had been ammoniated. Improved body weight gain of steers fed ammoniated rice straw obtained in a present study is similar to observations reported by others (Garrett et al., 1974; 1979; Ahn et al., 1984; Shin et al., 1985). However, the beneficial effect of ammoniation of rice straw was not seen when alfalfa hay was included in the diet. Maeng et. al. (1971), Paterson et al. (1981; 1982) and Brandt and Klopfenstein (1986) reported that positive associative effects could be expected when good quality forages such as alfalfa hay was combined with chemically treated or non-treated straws. Absence of a positive associative of alfalfa effect in present study may have been the result of low levels of rice straw included in the diet.

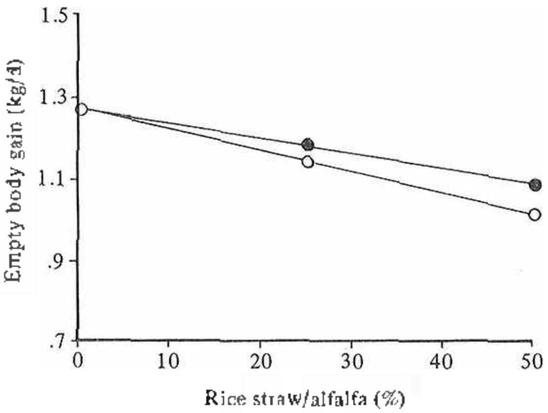

Figure 2. Empty body gain as affected by the level of untreated(●) and ammoniated (○) rice straw: alfalfa mixture in complete diets.

The volatile fatty acid composition of the rumen fluid from steers fed various experimental diets are summarized in table 4. The total VFA concentration in the rumen samples taken from steers receiving ARS was higher ($p < .05$) than those from steers receiving URS except in animals

TABLE 4. VOLATILE FATTY ACID COMPOSITIONS OF RUMEN SAMPLES FROM STEERS FED UNTREATED OR AMMONIATED RICE STRAW WITH AND WITHOUT ALFALFA HAY

		Rice straw				Rice straw/alfalfa				
		Untreated		Ammoniated		Untreated		Ammoniated		
Item	Basal	25	50	25	50	25	50	25	50	SE
Total VFA, moles/1	80.8	66.5 [cd]	55.8[d]	103.5[ab]	89.2[bc]	90.8[bc]	87.8[bc]	124.2[a]	76.6[cd]	4.38
VFA composition, mole/100 moles										
Acetate	41.4	57.1[bc]	59.5[b]	50.3[c]	58.8[c]	56.3[c]	60.4[b]	50.1[c]	58.8[c]	1.48
Propionate	41.4	25.3[b]	20.6[ab]	20.5[ab]	19.2[ab]	19.9[ab]	18.2[a]	31.8[c]	17.4[a]	2.74
Butyrate	11.7	14.2[a]	17.4[abc]	25.0[d]	19.8[bc]	20.1[c]	18.1[bcd]	14.6[a]	20.0[c]	1.72
Isovalerate	2.9	1.9[cd]	1.2[ab]	2.2[d]	.9[a]	2.0[d]	1.7[bcd]	1.3[abc]	2.1[d]	.23
Valerate	2.8	1.5[a]	1.3[a]	2.0[bc]	1.3[a]	1.7[ab]	1.6[ab]	2.2[c]	1.7[ab]	.16

[a,b,c]Means in the same row with different superscripts differ ($p < .05$). Means for the basal diet are given for comparison, but data from this treatment were not included in the statistical analysis

receiving 50 % rice straw: alfalfa mixture. Steers fed 25 % rice straw of rice straw: alfalfa diets showed higher total VFA concentration than those fed 50 % roughage diets. Mixing alfalfa hay with rice straw generally increased total VFA concentrations.

Rumen samples from steers fed URS and ARS containing diets were higher in acetic acid and lower in propionic acid concentration when compared with those of the basal diet. Increasing levels of roughage in the diets increased acetic acid and decreased propionic acid. Ammoniation of rice straw generally resulted in reduced concentrations of acetic and propionic acid, but increased concentration of butyric acid in the rumen fluid (except in the 25 % ARS: alfalfa diet).

The VFA data indicate that ammoniation of rice straw increased total VFA concentrations; this may be the result of improved digestion of rice straw by the ammonia treatment as reported by Terashima et al. (1981) and Maeng and Kim (1984).

Digestion trial

Table 5 shows dry matter and energy digestibility, and available energy contents of the experimental diets. *In vivo* and *in vitro* dry matter and energy digestibility were higher ($p < .05$) for the basal diet compared to all URS and ARS containing diets as expected. Diets containing 25 % roughage were more ($p < .05$) digestible than those containing 50 % roughage. The effect of ammoniation on dry matter or energy digestibility was generally positive. Mixing alfalfa hay with URS resulted in higher ($p < .05$) dry matter and energy digestibility of the diet compared to URS. On the other hand, the presence of alfalfa hay in the diets did not significantly affect digestibility when rice straw was ammoniated.

TABLE 5. DIGESTIBILITY AND AVAILABLE ENERGY CONTENTS OF EXPERIMENTAL DIETS

		Rice straw				Rice straw/alfalfa				
		Untreated		Ammoniated		Untreated		Ammoniated		
Items	Basal	25	50	25	50	25	50	25	50	SE
Dry matter dig.(%)	77.9	65.2^{b}	59.3^{a}	68.1^{a}	60.1^{a}	68.9^{cd}	63.7^{b}	70.0^{d}	65.5^{b}	.79
IVDMD (%)	91.9	79.1^{abcd}	76.8^{abcd}	82.6^{ab}	73.0^{cd}	81.2^{abc}	71.7^{d}	84.6^{a}	75.7^{bcd}	1.06
Energy dig.(%)	76.9	65.6^{b}	59.3^{a}	68.1^{a}	61.0^{a}	68.4^{c}	63.9^{b}	67.4^{c}	65.0^{b}	.86
DE (Mcal/kg)	3.41	2.74^{c}	2.33^{a}	2.86^{d}	2.44^{b}	2.92^{de}	2.68^{c}	2.99^{e}	2.76^{c}	.04
ME (Mcal/kg)	2.80	2.25^{c}	1.91^{a}	2.35^{d}	2.00^{b}	2.39^{de}	2.20^{c}	2.45^{e}	2.27^{c}	.03
NEm (Mcal/kg)	2.04	1.51^{c}	1.25^{a}	1.63^{de}	1.36^{b}	1.64^{de}	1.49^{c}	1.66^{e}	1.56^{cd}	.021
NEg (Mcal/kg)	1.61	1.06^{ab}	$.97^{a}$	1.22^{bc}	1.09^{abc}	1.19^{bc}	1.10^{abc}	1.25^{c}	1.22^{bc}	.042

a,b,c,d,e,f,g Means in the same row with different superscripts differ ($p < .05$). Means for the basal diet are given for comparison, but data from this treatment were not included in the statistical analysis.

Generally, diets containing ARS had higher ME values than comparable diets containing URS except 25 % RS: alfalfa diet. Also adding alfalfa to rice straw tended to increase ME values. Diets in which ARS replaced the basal mixture at 25 and 50 % had higher ($p < .05$) NEm and NEg values than comparable URS diets. This pattern was repeated when the straw : alfalfa mixtures replaced the basal, but differences between URS and ARS were significant only when the diet contained 50 % of the mixture.

The results of these trials indicate that NH_3 treatment did improve the feeding value of the rice straw when fed in completely mixed diets at 50 % level. However, the improvement was not readily apparent when the straw made up 25 % or less of a mixed diet. The reasons for improved performance of steers fed 50 % treated straw appeared to be an increased digestibility and energy availability, resulting in a greater intake of available energy. The experimental results also indicate that substituting alfalfa hay for 50 % of the URS resulted in improved digestibility of the diet and animal performance, but substituting alfalfa for 50 % of the ARS was less beneficial especially when ARS was only 12.5 % of the diet.

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