UTILIZATION OF RICE STRAW BY RUMINANTS AS INFLUENCED BY GRASS HAY SUPPLEMENTATION

In K. Han[1], J. K. Ha and W. N. Garrett[2]

Department of Animal Science and Technology, College of Agriculture and Life Sciences, Seoul National University, Suweon 441-744, Korea

Summary

Twenty Korean native bulls averaging 181 kg body weight were fed a fixed amount (1.5% of live weight) of concentrate and free choice roughage cubes which had four ratios of rice straw and orchard grass hay; 100:0, 85:15, 70:30 and 55:45 on a weight basis. Five bulls were assigned to each treatment and fed for 98 days in a confinement house. Nutrient digestibility and available energy content of mixed rations (40% concentrate and 60% roughage cubes) was determined in a digestion trial with twelve wethers. *In vitro* dry matter digestibility (IVDMD) and *in situ* dry matter disappearance of the roughage cubes were also determined. The ratio of grass hay to rice straw did not influence dry matter intake. Significant improvements in body weight gains and feed/gain ratios were obtained as grass hay levels increased. Average daily gain and feed/gain for each treatment was 0.83, 0.88, 0.98 and 0.99 kg; 7.63, 7.59, 6.83 and 6.41, respectively. Digestibility of the nutrients was improved with increasing levels of grass hay in the cubes. The IVDMD of roughage samples having a ritio of 100:0, 85:15, 70:30 and 55:45 between rice straw and orchard grass hay were 31.0, 37.1, 41.8 and 43.4%, respectively. Grass hay improved the IVDMD of rice straw diets in a linear manner up to 30%. *In situ* dry matter disappearance rate was also increased as the level of orchard grass hay increased.

(Key Words: Rice Straw, Bull Cattle, Grass Hay, Supplementation)

Introduction

Over 470 million metric tons of rice straw is produced in the world (FAO, 1984). However, the utilization of rice straw for feeding animals is limited because of its low nutrient content and poor digestibility (Devendra, 1982; Wanapat et al., 1984). Various chemical, physical or biological methods have been developed as a means of improving the nutritive value of rice straw. Although some treatments improve nutritive value and subsequent animal performance, treating rice straw usually requires expensive chemicals or energy input.

The supplementation of untreated or treated crop residues with concentrates or good quality roughages has been reported to improve dry matter digestibility, feed intake and subsequently performance of animals. The beneficial effects of supplementation may be explained by increased fiber digestion as a result of a more adequate supply of protein (Lyons et al., 1970) and minerals (Hunt et al., 1954; Coombe and Christian, 1969) for microbial growth, by improved palatibility of crop residues (Han et al., 1978) or by an increased nutrient supply to host animals from the supplements.

Addition of grasses and legumes to untreated and alkali-treated low quality crop residues has resulted in positive associative effects on DM digestibility and daily gain (Maeng et al., 1971; Paterson et al., 1981; 1982). However, no associative increase in energy utilization and animal performance by legume supplementation to untreated rice straw (Moran et al., 1983) and cornstalks (Paterson et al., 1981) was observed.

Objectives of present studies were to investigate effects of combinations of untreated rice straw and orchard grass hay on the growth of Korean native bulls and to assess the digestibility of these combinations with sheep.

[1]Address reprint requests to Dr. In K. Han, Department of Animal Science and Technology, College of Agriculture and Life Sciences, Seoul National University, Suweon 441-744, Korea.

[2]Department of Animal Science, University of California, Davis, CA 95616, USA.

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Materials and Methods

Feeding trial

Twenty Korean native bulls with an average weight to 181.5 kg were assigned to four treatment groups. The bulls had previously received the same diet for 2 months. Animals were housed in individual stalls with rubber mat floors, and were fed the experimental diets twice daily for 98 days. A fixed amount of concentrate (about 1.5% of live weight) was fed each day. The concentrate mixture, containing corn, wheat, sorghum, wheat bran, soybean meal, molasses, limestone, minerals and vitamin A, D, E, was formulated to contain 16.3% crude protein, 4.48 % crude fiber, 1.55% Ca and 0.59% P. Experimental roughage cubes were manufactured in a commercial rice straw pelleting machine to contain ratios of rice straw to orchard grass hay of 100:0, 85:15, 70:30 and 55:45. The experimental roughage cubes were offered free choice. Initial and final weights were the average of three full body weights obtained on consecutive days. Feeds offered and refused were recorded daily.

Digestion trial

Twelve Merino-Corriedale wethers averaging 48 kg body weight were used in a total collection digestion trial to determine the effects of the ratio of rice straw and orchard grass hay on nutrient digestion and rumen VFA concentrations. The treatments were the four ratios of rice straw to orchard grass hay (100:0, 85:15, 70:30 and 55: 45) used in the bull feeding trial. Lambs previ ously received a rumen cannula were kept in individual digestion crates. The lambs were fed 3% of body weight with a constant ratio between concentrate and roughage (40:60). Feces were collected for five days after a 7 day adjustment period. A 10% (by weight) sample of daily feces was composited for each lamb, dried in an forced-air oven at 60℃ and stored for later analysis.

After the digestion trial, rumen samples were collected from the ventral sac of each animal for the determination of pH and volatile fatty acid (VFA) concentrations. Samples were collected with a suction tube 3 hr after feeding and strained through four layers of cheesecloth. A general purpose glass electrode was used to measure rumen fluid pH. Microbial activity of the sample was stopped by adding a few drops of saturated mercuric chloride solution. For the VFA determination, 2.5 ml of strained rumen fluid was acidified and centrifuged at 2,000 rpm for 20 min as outlined by Erwin et al. (1961). Gas liquid chromatography as described by Baumgardt (1964) was used to determine VFA concentration in the supernatant.

In vitro and *in sacco* trial

Twelve wether lambs used in the digestion trial were maintained on the same diets to determine the rate of dry matter disappearance of four experimental roughages *in situ*. These animals were also the donors of rumen fluid for the determination of *in vitro* dry matter digestibility (IVDMD) as described by Tilley and Terry (1963). In the *in sacco* trial, roughage samples were ground in a Wiley mill with a 2 mm screen. Duplicate samples (0.5 g) of each experimental roughage mixtures were placed in 20 × 15 cm bags on nylon cloth (Thompson & Co. Ltd., Montreol) having an average mesh size of 48 μm and then incubated for 6, 12, 24, 36, 48, 60 or 72 hours in the rumen of lambs fed the same roughage mixture. After retrieval, bags were rinsed with cold tap water and dried at 60℃. Two bags from each treatment which were not incubated were also washed as described. Dry matter disappearance rate was calculated as outlined by Ha and Kennelly (1984).

Proximate analysis of feed, refusal and feces were determined by the method of AOAC (1984). Cell wall components were determined by the method of Goering and Van Soest (1970), trace minerals by atomic absorption spectrometer and gross energy by bomb calorimetry. All data collected were subjected to analysis of variance. When F values indicated a significant ($p < .05$) difference, treatment means were compared at a probability of .05 using Ducan's multiple range test (Steel and Torrie, 1960).

Results and Discussion

Feeding trial

Nutrient composition of the rice straw, orchard grass hay, and various combinations of two roughage sources are presented in table 1 and 2. Rice straw contained a very low level of crude protein (approximately half of orchard grass hay). Rice straw was slightly higher in NDF, ADF

and hemicellulose, but orchard grass hay was higher in cellulose. Rice straw was much higher in ash and silica (55% of ash in rice straw) than orchard grass hay as reported in other studies (Sharma, 1974; Jackson, 1977; Lee et al., 1983). Orchard grass hay contained higher levels of minerals except Fe, Cr and Mn. Mineral levels in rice straw obtained in the present study are different from those reported by others (Jackson, 1977; Han and Garrett, 1986). This is probably due to differences in straw variety, location and cultural practices (Jackson, 1977).

Live weight gain, feed intake and feed/gain of Korean bull calves fed experimental diets are presented in table 3. Bulls fed higher levels of orchard grass gained more compared with those fed higher rice straw diets. Each 15% increment of grass hay in the roughage cube improved weight gain by 6, 18 and 19% over the 100% rice straw group. Only the gains made by the bulls fed the two higher levels of orchard grass were higher ($p < .05$) than the rice straw only group. The intake of concentrate and roughage cubes was not significantly influenced by dietary treatment. Feed/gain decreased ($p < .05$) as level of orchard grass hay in the roughage increased to 30 and 45% (10% and 16% increase over the rice straw controls).

TABLE 1. NUTRIENT COMPOSITION OF RICE STRAW AND ORCHARD GRASS HAY

Nutrients[1]	Roughage	
	Rice straw	Orchard grass hay
Crude protein (%)	4.6	9.3
Ether extract (%)	1.6	1.4
Crude ash (%)	17.9	8.0
NDF (%)	71.6	68.1
ADF (%)	47.8	45.7
Hemicellulose (%)	23.8	22.4
Cellulose (%)	30.3	36.4
Lignin (%)	6.0	8.1
Silica (%)	9.8	.57
Ca (%)	.36	.80
P (%)	.11	.32
Na (%)	.07	.12
K (%)	.93	3.48
Mg (%)	.65	1.81
Fe (%)	.06	.04
Cu (mg/kg)	1.90	6.48
Co (mg/kg)	1.90	2.14
Zn (mg/kg)	2.30	4.48
Cr (mg/kg)	2.86	2.21
Mn (mg/kg)	301	204

[1] Dry matter basis

TABLE 2. NUTRIENT COMPOSITIONS OF ROUGHAGE CUBES, %

Nutrient[1]	Ratio of rice straw and orchard hay (%)			
	100 : 0	85 : 15	70 : 30	55 : 45
Crude protein	4.6	5.5	6.3	7.7
Ether extract	1.6	1.6	1.5	1.4
Crude ash	17.9	15.8	13.8	12.4
Crude fiber	25.7	26.5	29.6	29.4
NDF	71.6	71.1	71.0	69.7
ADF	47.8	47.5	47.6	46.2
Hemicellulose	23.8	23.6	23.3	23.5
Cellulose	30.3	31.8	33.2	33.1
Lignin	6.0	6.4	6.6	7.3
Silica	9.8	9.7	8.5	5.4
Ca	.35	.40	.45	.53
P	.10	.13	.15	.21

[1] Dry matter basis.

Previously reported results are conflicting. Mbatya et al. (1985) indicated that supplementation with grass did not affect straw intake, while others (Mosi and Butterworth, 1985) observed reduced straw intake, but increased total dry matter intake when supplemented with legume

hay. Also it appears that effect of legume supplementation on feed intake might be altered by alkali treatment. Moran et al. (1983) reported that alkali-treated rice straw supplemented with alfalfa increased straw intake by up to 30%, but the same treatment depressed the intake of untreated rice straw. Animals used in present study may have received enough energy and crude protein from concentrate. Improved body weight gain and feed/gain may be attributed to increased nutrient digestibility and available energy in the diets containing 30 and 45% of the roughages as orchard grass (table 4). Similar response with Korean native bulls has been reported by Ahn et al. (1984), who compared the growth of bulls fed rice straw with or without grass hay.

TABLE 3. BODY WEIGHT GAIN, FEED INTAKE AND FEED: GAIN RATIO OF KOREAN BULLS AS AFFECTED BY THE RATIO OF RICE STRAW AND ORCHARD GRASS HAY

Treatment (RS:OG)[1]	Initial body wt.	Final body wt.	Total gain	Avg. daily gain	Feed intake		Feed/Gain
					Concentrate	Roughage	
	kg						
100:0	181.6±8.7[2]	263.4±1.4	81.8±4.0[a]	.83±.04[a]	2.71±.12	3.62±.18	7.63±.22[a]
85:15	181.6±7.7	268.3±9.6	86.7±4.1[ab]	.88±.04[ab]	2.68±.10	4.01±.20	7.59±.19[a]
70:30	181.4±5.0	277.7±7.5	96.3±4.3[b]	.98±.05[b]	2.75±.07	3.94±.18	6.83±.12[b]
55:45	181.2±6.6	278.1±7.6	96.9±3.9[b]	.99±.04[b]	2.78±.08	3.53±.12	6.41±.19[b]

[1] RS:OG is ratio of rice straw and orchard grass hay.
[2] Values are the mean±SE.
[a,b] Means in the same column with different superscripts differ ($p < .05$).

TABLE 4. NUTRIENT DIGESTIBILITY AND AVAILABLE NUTRIENTS OF EXPERIMENTAL DIETS IN SHEEP[1]

Treatment (RS:OG)[2]	Digestibility (%)			
	Dry matter	Crude protein	Ether extract	Crude fiber
100:0	50.2± .84[a]	59.1±3.92[a]	69.1±6.84[a]	29.2±2.80[a]
85:15	50.7±1.94[a]	66.0±1.34[b]	72.1±3.69[ab]	26.2±3.27[a]
70:30	56.1± .59[b]	71.5± .49[b]	78.9± .47[ab]	44.6±1.04[b]
55:45	58.2±1.04[b]	68.9±1.35[b]	81.7±1.79[b]	37.7±2.30[b]

Treatment (RS:OG)[2]	Digestibility (%)			TDN (%)	DE (Mcal/kg)
	NFE	NDF	ADF		
100:0	48.7±2.33[a]	38.2±1.65[a]	24.0±2.06[a]	57.8± .64[a]	2.03± .03[a]
85:15	50.7±1.94[a]	34.8±2.79[a]	20.6±4.32[a]	57.2± .99[a]	2.05± .07[a]
70:30	56.1± .59[b]	41.6± .31[b]	33.7±1.69[b]	61.9± .33[b]	2.29± .02[b]
55:45	58.2±1.04[b]	47.3±1.26[b]	35.1±1.79[b]	60.7± .51[b]	2.34± .05[b]

[1] All values are reported in means±SE.
[2] RS:OG is ratio of rice straw and orchard grass hay.
[a,b] Means in the same column with different superscripts differ ($p < .05$).

Digestion trial

Substituting grass hay for rice straw significantly increased the digestibility of all the nutrients in a linear manner. The increase was most apparent when the level of orchard grass was 30% or more of the roughage. Present results clearly show that grass hay substitution for rice straw improved nutrient digestion without a sig-

nificant increase in feed intake and this probably explains the improved animal performance. The significant improvement in protein digestibility by the addition of grass may have been the effect of increased level of dietary crude protein as discussed by Ha and Kennelly (1984).

Paterson et al. (1982) reported the dry matter digestibility of corn cob was increased by 8% when alfalfa was added to the diet. A similar associative effect on digestibility has been reported by Maeng et al. (1971). In the current study, digestibility of a total mixed diet was determined without a digestion trial for the individual roughage sources. Therefore, it is not possible to determine whether digestibility of rice straw was improved by grass hay supplementation. Positive associative increase in digestion of rice straw could be possible if additional protein and mineral from grass hay stimulated microbial activity (Burroughs et al., 1950; Hunt et al., 1954).

No major differences were observed in rumen pH and VFA concentrations (table 5) except that concentrations of isovaleric and valeric acids were increased with high levels of grass hay.

TABLE 5. VFA CONCENTRATIONS AND RUMINAL pH AS INFLUENCED BY THE RATIO OF RICE STRAW AND ORCHARD GRASS HAY

Treatment	Total VFA	*Composition (%)*					*Ruminal*
(RS:OG)[1]	mmole/L	Acetic	Propionic	Butyric	Isovaleric	Valeric	pH
100:0	115.6±4.1[2]	52.4±2.1	33.3±2.1	12.8± .1	.65±.14[a]	.86±.04[a]	6.35±.15
85:15	113.2±9.1	53.5±4.1	30.9±4.1	13.6±1.0	.93±.03[a]	1.20±.12[c]	6.47±.09
70:30	103.7±4.9	54.2±1.7	29.7±4.5	14.1± .5	.94±.07[ab]	1.12±.02[ab]	6.50±.06
55:45	124.4±5.6	53.0±2.7	32.9±3.1	12.8± .9	1.10±.08[b]	1.14±.05[bc]	6.50±.01

[1] RS:OG is ratio of rice straw and orchard grass hay.
[2] All values are reported in means±SE.
[a,b,c] Means in the same column with different superscripts differ ($p < .05$).

In vitro and *in sacco* trial

In vitro dry matter digestibility (IVDMD) of experimental roughages used in the bull feeding and the lamb digestion trial was improved as the level of orchard grass hay increased in the roughage cube. The magnitude of improvement in IVDMD by including grass hay at 15%, 30 % and 45% was 6.1%, 4.7% and 1.6% units, indicating a positive response which declined in magnitude as the level of grass hay increased. The IVDMD of orchard grass hay was 45.4± 2.13%. When IVDMD of rice straw and orchard grass mixtures (85:15, 70:30 and 55:45) were calculated based on the IVDMD of rice straw and orchard grass, the results was 33, 35 and 37%. Therefore, determined IVDMD of grass supplemented rice straw were higher than calculated values by 12, 18 and 16%. This is an evidence for a positive associative effect of orchard grass on rice straw IVDMD. Positive associative effects of grass-rice straw combinations observed in present study is in agreement with the data of Paterson et al. (1981) and Brandt and Klopfenstein (1986). The IVDMD of untreated rice straw has been reported as 32.2% to 35.8% (Willis et al., 1980), 37% (Devendra, 1983) and 33.6%-38.3% (Maeng et al., 1979). The value obtained in the present study is slightly lower (31%), possibly due to the difference in variety and growing conditions.

TABLE 6. *IN VITRO* DRY MATTER DIGESTIBILITY (IVDMD) OF ROUGHAGE MIXES

Treatment (RS : OG)[1]	IVDMD (%)[2]
100:0	31.0±3.76[a]
85:15	37.1±1.94[ab]
70:30	41.8±4.18[b]
55:45	43.4±1.45[b]

[1] RS:OG is ratio of rice straw and orchard grass hay.
[2] Values are reported in means±SE.
[a,b] Means with different superscripts differ ($p < .05$).

In sacco dry matter disappearance of roughages mixtures is given in table 7. Except at 0 and 6 hr incubation time, DM disappearance were

higher when rice straw was replaced with orchard grass, but among grass hay levels, no significant differences were found in DM disappearance rate. The reason for the higher DM disappearance rate of rice straw (100:0) and the 15% grass hay mixtures early during incubation is not apparent, but could reflect some readily fermentable component of rice straw. However, disappearance rate at the early phases of incubation is influenced more by sample particle size than by actual microbial digestion (Ha and Kennelly, 1984).

Dry matter digestibility may be calculated from nylon bag disappearance if solid outflow rate is determined for each sample. Linberg (1983) claimed that *in vivo* DM digestibility could be predicted from DM disappearance at 48 hr incubation time. Since *in vitro* method (Tilley and Terry, 1963) adapts 48 hr incubation, it might be logical to compare IVDMD and 48 hr disappearance data. However, data presented in table 6 and 7 indicate that *in situ* DM disappearance was much higher than IVDMD. Therefore, it appears that direct comparison of DM digestibility measured by two different methods are not sound.

TABLE 7. DRY MATTER DISAPPEARANCE OF ROUGHAGE MIXES FROM NYLON BAGS SUSPENDED IN THE RUMEN OF SHEEP (%)

Treatment (RS:OG)[2]	Incubation time (hr)[1]			
	0	6	12	24
100:0	22.9± .4[a]	31.7± .5[ab]	35.9± .8[a]	45.6± .8[a]
85:15	23.9± .2[a]	32.0± .3[a]	37.9±1.2[ab]	48.7±1.3[b]
70:30	19.7± .4[b]	28.1± .3[b]	40.5± .5[b]	50.2± .4[b]
55:45	21.3± .6[ab]	29.4±1.3[ab]	39.2± .8[b]	50.1±1.3[b]

Treatment (RS:OG)[2]	Incubation time (hr)[1]			
	36	48	60	72
100:0	49.7±1.7[a]	54.3±1.4[a]	55.6±1.8[a]	55.7±2.1[a]
85:15	53.8± .3[b]	56.5± .9[ab]	58.6± .5[ab]	59.7± .2[b]
70:30	54.9± .2[b]	59.4± .1[b]	60.6± .7[b]	61.2± .6[b]
55:45	53.7± .4[b]	57.7± .6[b]	60.0± .7[b]	61.9± .6[b]

[1] All values are reported in means±SE.
[2] RS:OG is ratio of rice straw and orchard grass hay.
[a,b] Means in the same column with different superscripts differ ($p < .05$).

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