STUDY ON THE UTILIZATION OF RICE STRAW BY SHEEP
1. THE EFFECT OF SOYBEAN MEAL SUPPLEMENTATION ON THE VOLUNTARY INTAKE OF RICE STRAW AND RUMINAL FERMENTATION

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Summary

The study was conducted to investigate the effect of soybean meal (SBM) supplementation on the voluntary intake of rice straw and ruminal fermentation characteristics. Balance trials were conducted with three Japanese Corriedale wethers fed a rice straw alone (control), rice straw supplemented with 75 and 150 g of SBM/day in a 3 × 3 latin square design. Voluntary intake of rice straw in sheep fed both levels of SBM supplemented diets was significantly higher ($p < 0.05$) than that in sheep fed control diet. Crude protein digestibility was significantly increased ($p < 0.05$), but organic matter, crude fibre, neutral detergent fibre and acid detergent fibre digestibilities were not affected by SBM supplementation. Nitrogen balance was positive in sheep on both levels of SBM supplemented diets, but negative in animals on the control diet. Rumen ammonia and blood urea-nitrogen concentrations increased ($p < 0.05$) as increasing level of SBM. Total volatile fatty acids, acetate, propionate, butyrate and valerate concentrations in rumen fluid were also significantly increased ($p < 0.01$), but ruminal pH was decreased ($p < 0.05$) by SBM supplementation.
(**Key Words** : Rice Straw, Soybean Meal, Intake, Rumen Fermentation)

Introduction

Low quality roughage such as rice straw is widely used as a source of feed for ruminant animals, particularly in many tropical countries during the dry season. However, the main limiting factors in the utilization of straw as a feed are related to the low voluntary intake, low digestibility, high fibre content and deficiencies of other nutrients to support animal production.

Recently, considerable efforts of many animal nutritionists have been directed to improvement of the nutritive value of rice straw and its utilization (Itoh et al., 1979, Liu et al., 1988, and Hoek et al., 1988). These results suggested that the nutritional limitations could be overcome by physical and chemical treatments or by supplementation with specific nutrients to provide an optimum ruminal condition for rumen microorganisms. Church and Santos (1981) reported that soybean meal (SBM) supplementation to wheat straw diets increased digestibility and consumption of the straw by heifers. Similar result was also demonstrated by Guthrie and Wagner (1988) for low quality prairie hay in cattle. They showed that dry matter (DM), organic matter (OM), crude protein (CP) and acid detergent fibre (ADF) digestibilities and intake of the hay were greatly improved by SBM supplementation. In contrast, Liu et al. (1988) reported that voluntary intake of rice straw was only slightly increased by SBM supplementation in sheep. Furthermore, they suggested that the intake of rice straw was difficult to increase by nitrogen supplementation alone, and the increasing nitrogen supply to the rumen microbes was not necessary associated by increasing fibre digestion.

It is expected that with proper supplementation, rice straw could be used successfully as a major component of ruminant diet, especially at or slightly above maintenance feeding level. Objective of this study was to examine the effect of SBM supplementation on the voluntary intake of rice straw and ruminal fermentation characteristics in sheep.

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Materials and Methods

Animal management and experimental diets

Three rumen-fistulated Japanese Corriedale wethers, with an initial body weight (mean ± SD) of 42 ± 3.5 kg were used in a 3 × 3 latin square design. Each experimental period lasted for 13 days, consisted of 7-day preliminary, 5-day feces and urine samples collection, and 1-day ruminal fluid sample collection periods. Each sheep was fed with one of the three treatment diets as follows : ① rice straw alone (control), ② rice straw + 75 g of SBM/day (0.18% of BW), and ③ rice straw + 150 g of SBM/day (0.36% of BW). Before starting the experiment, all sheep were treated with "Thybenzole 75%" (90 mg/kg BW) to control gastro-intestinal roundworms. The rice straw was of *Nipponbare* variety and stored for about 6 months before used. The straw was chopped into 1-2 cm length and was offered *ad libitum*, i.e. 25% greater than the amount on the previous day consumed. The daily allowance of straw and supplement was given in two equal portions at 09:00 and 17:00 h. In addition, supplement was given just before feeding rice straw. Water and mineralized block salt were freely available. Refused rice straw was removed and weighed everyday just before morning feeding. A part of the daily refusal was bulked over 5-day collection period. There was no residue obtained from the supplement throughout the experimental period. The chemical composition of rice straw and SBM used in this study is shown in table 1. During a 5 day sample collection period, daily total feces from each sheep was collected and dried in a forced air oven at 60℃ for 24 h. The samples then were composited and ground through 1 mm screen for analysis. Daily urine was also collected and 50 ml of 10% H_2SO_4 were added to prevent the loss of nitrogen. On the final day of each experimental period, approximately 50 ml ruminal fluid sample from each sheep were taken just before and at 1, 2, 3, 5 and 7 h after morning feeding. Urine and ruminal fluid samples were stored at −20℃ for further analyses.

TABLE 1. CHEMICAL COMPOSITION OF RICE STRAW AND SOYBEAN MEAL (% OF DRY MATTER)

Constituent	Rice straw	Soybean meal
Organic matter	82.3	93.1
Crude protein	3.6	44.3
Crude ash	17.7	6.9
Crude fat	1.9	0.4
Nitrogen free-extract (NFE)	43.9	43.5
Crude fibre	32.8	4.9
Neutral detergent fibre (NDF)	73.8	12.6
Acid detergent fibre (ADF)	55.5	8.4
Lignin	5.8	–
Silica	12.4	–

Laboratory analysis

The chemical composition of rice straw, feces and rice straw refusal were analyzed according to the Association of Official Agricultural Chemists (AOAC, 1984). Neutral detergent fibre (NDF), ADF, lignin and silica contents were determined according to the methods of Goering and Van-Soest (1970). Nitrogen in urine was analyzed by the Kjeldahl Method (AOAC, 1984). The rumen fluid sample was analyzed for ammonia (Oser, 1965), and total and individual volatile fatty acids (VFAs) concentrations were analyzed by gas chromatography (Erwin et al., 1961).

Statistical analysis

All data were subjected to analysis of variance for a 3 × 3 latin square, and difference among the treatment means were determined by the least significant difference method (Steel and Torrie, 1981).

Results and Discussion

No differences were observed in terms of chemical composition between the rice straw given and refusal. Organic matter, CP, crude fibre (CF), NDF, and ADF contents of rice straw in this study were relatively lower than results reported previously (Harumoto and Kato, 1979 and Liu et al., 1988). This difference might be due to different fertilizer application during the rice grew and storage method between the rice straw used. However, there were in comparable with data obtained by Devendra (1975) from 7 varieties of rice straw in Malaysia. As shown in table 1, the rice straw used in this study contained

3.6% CP, which was far below the critical level of CP required (7%) for normal forage consumption by sheep (Minson, 1967). The supplementation of 75 and 150 g SBM increased CP content of the entire diets to 7.1 and 10.1%, respectively.

Table 2 shows voluntary intake of rice straw, changes of body weights and apparent digestibilities. The voluntary intake of rice straw was significantly increased ($p < 0.05$) by SBM supplementation. The increase was approximately 47

TABLE 2. EFFECT OF SOYBEAN MEAL SUPPLEMENTATION ON THE VOLUNTARY INTAKE OF RICE STRAW, WEIGHT GAIN AND DIGESTION IN SHEEP FED RICE STRAW AS A BASAL DIET

Item	Level of soybean meal (g/day)			SEM[1]
	0	75	150	
Rice straw intake:				
(g DM/day)	540.4[a]	791.7[b]	794.4[b]	53.4
(g DM/kg $BW^{0.75}$)	32.1	46.1	46.0	3.5
TDN intake (g/day)	239.5[c]	439.7[d]	494.8[d]	27.4
Weight gain (g/day)	−190.0[c]	−12.0[d]	35.0[d]	23.5
Digestibility (%):				
Organic matter	52.7	60.1	61.6	2.5
Crude protein	23.7[c]	59.2[d]	74.0[d]	3.8
Crude fibre	62.0	66.0	64.6	1.7
NDF	47.8	53.0	51.0	3.5
ADF	42.8	46.0	45.9	3.3

[abcd] Values in the same row with different superscripts differ significantly (a,b: $p < 0.05$; c,d: $p < 0.01$).
[1] Standard error of the mean.

% in both 75 and 150 g of SBM levels, and it was probably due to enhancing cellulolysis and increasing the rate of breakdown of cell walls in the reticulorumen, and partly to effect on metabolism in the body tissues, as proposed by Weston (1967). The voluntary intake of rice straw in this study was higher than results obtained by Liu et al. (1988). The mean intake of rice straw calculated from their study was improved by 17, 22 and 24% with supplementation of 100, 200 and 300 g of SBM/day (0.12, 0.25 and 0.37% of BW), respectively. The reason for difference in response to SBM supplementation was probably due to the difference in quality of rice straw and SBM used. The CP content of rice straw and SBM in their study was 5.4 and 52.1%, whereas in this study it was 3.6 and 44.3%, respectively. The following workers have also shown some positive effects of SBM as a source of protein supplement to improve utilization of low quality roughages. Church and Santos (1981) reported that SBM supplementation to wheat straw diet significantly increased the straw consumption and digestible energy intake by heifers. Guthrie and Wagner (1988) showed a 30.6 and 44.6% increased in intake of low quality prairie hay (5.2% CP) in steers fed 362 g of SBM (0.17% of BW) and 603 g of SBM (0.28% of BW) supplementation. In this study, however, the increasing level of SBM from 75 to 150 g/day (0.18 to 0.36% of BW/day) did not further increased the rice straw consumption. This finding was in agreement with the results obtained by Church and Santos (1981) and Liu et al. (1988).

Sheep could not maintain their body weights and lost an average of 190 g/day when fed a rice straw alone. The inclusion of SBM in the diets significantly increased ($p < 0.01$) the daily gain. This result was consistent with the report of Devendra (1978), who showed that rice straw was insufficient to maintain the live weight of sheep due to a low voluntary intake and a low digestible energy content, when it was given as a sole diet. This finding suggests that the improvement on daily gain of sheep fed SBM supplemented diets was due to the additional digestible energy and protein, and other essential nutrients

supplied by the supplement, and through the increased intake of the straw. Daily intake of total digestible nutrients (TDN) in sheep fed rice straw alone, rice straw supplemented with 75 and 150 g of SBM/day were 240, 440, and 495 g, respectively. The later two values could meet or had slightly higher from the TDN requirement for maintenance of sheep weighing 40 kg, as recommended by NRC (1975). Organic matter, CF, NDF and ADF digestibilities tended to be higher in sheep given SBM supplemented diets than those sheep under control diet. However, CP digestibility in sheep fed control diet was significantly lower ($p < 0.01$) when compared with sheep fed both levels of SBM supplemented ones. The absence of a significant improvement in fibre digestion when straw supplemented with SBM was consistent with the previous experiments (Church and Santos, 1981 and Liu et al., 1988). In addition, the low CP digestibility in sheep given a rice straw alone was probably caused by relatively higher metabolic fecal nitrogen excretion.

As expected, the increasing levels of SBM from 0 to 75 and 150 g/day resulted in increasing nitrogen intake from 2.20 to 8.23 and 13.45 g/day, respectively, and it was also accompanied by increasing urinary nitrogen excretion ($p < 0.01$). However, SBM supplementation had no significant effect on the fecal nitrogen excretion. Nitrogen retention was negative for sheep fed control diet and it was significantly increased ($p < 0.01$) by supplementation of 75 and 150 g of SBM/day (table 3). The increasing nitrogen retention due to protein supplementation to low

TABLE 3. EFFECT OF SOYBEAN MEAL SUPPLEMENTATION ON THE NITROGEN BALANCE IN SHEEP FED RICE STRAW AS A BASAL DIET

Nitrogen (g/day)	Level of soybean meal (g/day)			SEM[1]
	0	75	150	
Intake	2.20[a]	8.23[b]	13.45[c]	0.8
Loss in feces	1.92	3.22	3.45	0.6
Loss in urine	2.36[a]	4.77[b]	8.26[c]	0.1
Retention	−2.08[a]	0.24[b]	1.74[c]	0.4

[abc] Values in the same row with different superscripts differ significantly ($p < 0.01$).
[1] Standard error of the mean.

quality forage in sheep has also been reported by Caton et al. (1988). The negative nitrogen balance in sheep fed control diet reflected directly the low content and low digestibility of nitrogen of rice straw and relatively high urinary nitrogen excretion. When expressed as percent of intake, urinary nitrogen excretion was 107, 58, and 60 % for sheep fed 0, 75 and 150 g of SBM supplemented diets, respectively. Church and Fontenot (1984) also pointed out that nitrogen excreted in the urine was greatly dependent on the level of nitrogen intake, that was higher on low and high level of nitrogen intake but minimum at medium intake.

The effect of SBM supplementation on the ruminal pH is shown in figure 1. There were significant differences ($p < 0.05$) between the SBM supplemented and control diets at all sampling times, and the maximum values were achieved at 2 h in all sheep. Average ruminal ammonia

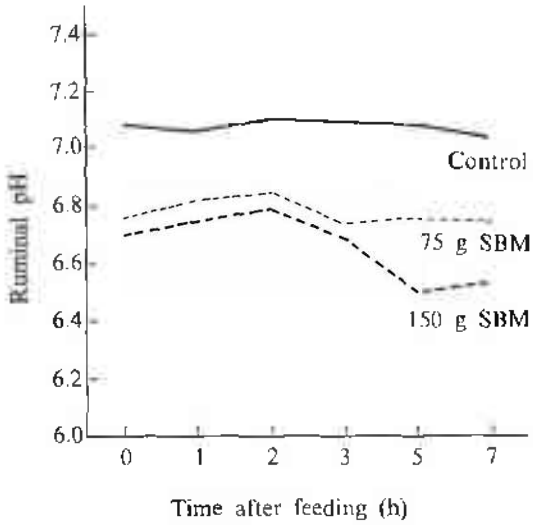

Figure 1. Ruminal pH of sheep fed rice straw supplemented with various levels of soybean meal (SBM).

concentrations based on the six sampling times values significantly increased ($p < 0.05$) from 3.4 to 9.7 and 15.2 mg/100 ml in sheep fed 0, 75 and 150 g of SBM supplemented diets, respectively (figure 2). The increasing level of ruminal

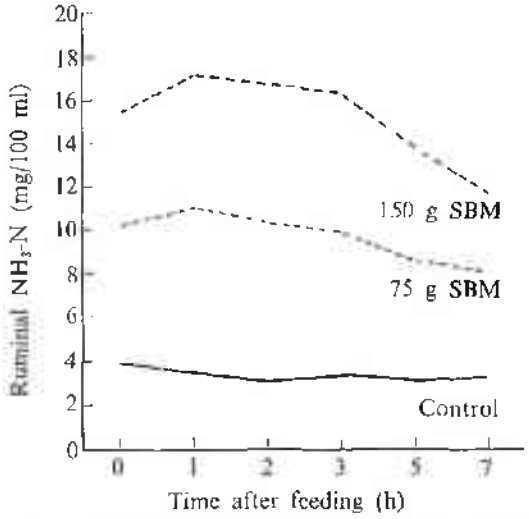

Figure 2. Ruminal NH_3-N concentrations of sheep fed rice straw supplemented with various levels of soybean meal (SBM).

ammonia concentration from 9.7 to 15.2 mg/100 ml was not associated by increasing intake and digestibility of rice straw. This finding supported the result of Milne et al. (1979) that intake of heather (*Calluna vulgaris*, L. Hull) by sheep was no further improvement with increasing ruminal ammonia concentration above 6 mg/100 ml. However, it was not consistent with data obtained by Perdok et al. (1988) that maximum intake and digestibility of rice straw by cattle were achieved at about 10 and 20 mg/100 ml ammonia concentration levels, respectively. *In vitro* study of Satter and Slyter (1974) demonstrated that an ammonia concentration of 5-8 mg/100 ml in the rumen fluid was sufficient to support maximal rates of microbial growth. Increasing the ammonia concentration above this level resulted no further increase in microbial production. The increasing ruminal ammonia concentrations due to SBM supplementation to low quality roughage have also been reported by several workers (Rooke et al., 1986 and Krysl et al., 1989). Furthermore, Satter and Roffler (1981) obtained that ammonia concentration normally fluctuates, reaching a peak at about 1 to 2 h following feeding, and then decreasing. In this study, the peak of ammonia concentrations were occurred at 1 h after feeding in sheep fed both 75 and 150 g of SBM supplemented diets.

Blood urea-nitrogen (BUN) concentration was significantly increased ($p < 0.05$) by SBM supplementation (figure 3), and it could be reflected

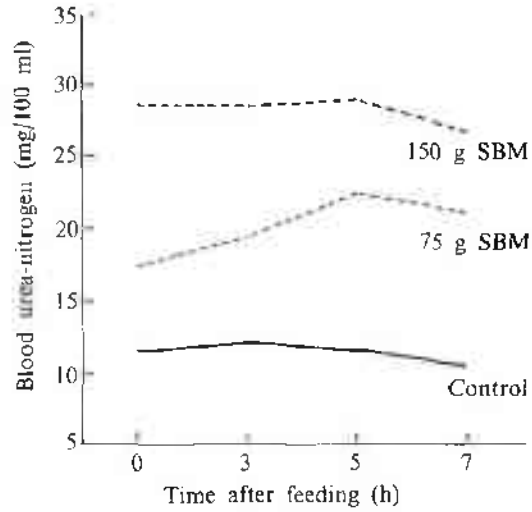

Figure 3. Blood urea-nitrogen concentrations of sheep fed rice straw supplemented with various leve s of soybean meal (SBM).

directly the rate of ruminal NH_3 concentration and its absorption through the rumen wall. The average levels were 11.5, 20.1 and 28.2 mg/100 ml for sheep fed 0, 75 and 150 g of SBM supplemented diets, respectively. These values were in the range or above the normal level (8-20 mg/100 ml) as reported by Swenson (1977). Total VFAs, acetate, propionate, butyrate, and valerate concentrations in rumen fluid, based on the six sampling times values, were also increased ($p < 0.01$) by increasing level of supplement in the diets (table 4). The higher VFAs concentrations in sheep fed SBM supplemented diets indicated that more quantities of organic matter being fermented in the rumen.

These results have clearly shown that the utilization of rice straw as a ruminat feed could be increased by soybean meal supplementation, and the maximum utilization appeared to have been achieved at the level of 75 g of SBM/day.

TABLE 4. EFFECT OF SOYBEAN MEAL SUPPLEMENTATION ON THE TOTAL AND INDIVIDUAL VFA CONCENTRATIONS IN RUMEN FLUID OF SHEEP FED RICE STRAW AS A BASAL DIET

Item	Level of soybean meal (g/day)			SEM[z]
	0	75	150	
	(mmol/dl)			
Total	4.56[a]	6.26[b]	7.23[c]	0.13
Acetate	3.53[a]	4.67[b]	5.42[c]	0.09
Propionate	0.73[a]	1.07[b]	1.11[c]	0.02
Butyrate	0.28[a]	0.40[b]	0.58[c]	0.03
Valerate	0.03[a]	0.09[b]	0.11[c]	0.004

[y] Each value is the mean of six sampling times values.
[a,b,c] Values in the same row with different superscripts differ significantly ($p < 0.01$)
[z] Standard error of the mean.

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