STUDIES ON THE UTILIZATION OF RICE STRAW BY SHEEP
Ⅳ. EFFECT OF SOYBEAN MEAL AND BARLEY SUPPLEMENTATION ON EATING AND RUMINATION BEHAVIOR

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Summary

A 3 × 3 latin square design experiment was conducted to study eating and rumination behavior in sheep fed rice straw (RS) supplemented with soybean meal (SBM) and barley at three different levels of crude protein: low (40 g CP/d, LCP), medium (67 g/d, MCP) and high (94 g/d, HCP). In addition, all the supplements were formulated to contain the same amount of total digestible nutrients (TDN; 275 g). Daily time spent eating and eating rate of RS were not affected by any supplementation. However, time spent ruminating in sheep fed HCP diet was markedly shorter ($p < 0.05$) than in those fed LCP and MCP diets. Rumination index (ruminating time/100 g DM intake) was also significantly reduced ($p < 0.05$) by increasing level of protein supplementation.

Although no significant differences were observed, the daily number of rumination periods tended to be lower, while daily number of boli regurgitated was considerably higher in sheep fed HCP diet than in those fed LCP and MCP diets. Increasing level of protein supplementation did not affect the number of chews per bolus, bolus time and rate of chewing during rumination. It is suggested that increasing level of protein supplementation was associated with more effective microbial reduction of rumen digesta particle size and consequently reduced the time spent ruminating.
(**Key Words**: Rice Straw, Soybean Meal, Barley, Rumination Behavior)

Introduction

It is well known that voluntary intake and digestibility of rice straw (RS) by ruminants may be limited by a deficiency of nitrogen and high level of cell wall (Preston and Leng, 1984). Supplementation of RS based diets with nitrogen or concentrates has been reported to overcome these nutritional limitations, increase voluntary intake and digestibility, and hence increase animal performance (Church and Santos, 1981; Warly et al., 1992a). According to Nicholson (1984), nitrogen deficiency is the primary limiting factor in the utilization of straws and other low-quality roughages by ruminants, since maximum digestion requires adequate degradable protein to meet the needs of rumen microorganisms. Rice straw as a feedstuff also contains very low levels of fermentable carbohydrates because a large amount of energy stored in hemicellulose and cellulose is not readily available for digestion by rumen microorganisms. Therefore, to get maximum fiber digestion by rumen microorganisms, the adequacy of both nitrogen and energy of supplements have to be considered.

Campling (1969) has pointed out that voluntary intake of low-quality roughages, such as straw, by ruminants is controlled partly by physical factors, especially the rate of breakdown of rumen digesta and its passage through the reticulo-omasal orifice. The breakdown of digesta particle size is accomplished by chewing during eating and rumination, microbial fermentation and rumen movements (Reid et al., 1977). In a study reported earlier, increased voluntary intake and digestibility of RS due to protein (soybean meal, SBM) supplementation (Warly et al., 1992a), was associated with reduction of rumination activity (Warly et al., 1992b). However, they showed that increasing level of SBM from 75 to 150 g/d did not further stimulate intake, digestion and characteristics of rumination. Harumoto

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Received September 4, 1993
Accepted February 24, 1994

and Kato (1979) suggested that supplementation of wheat bran to rice straw diet had some effects on the rumination behavior in relation to the changes in ruminal fermentation.

Objectives of the present study were to evaluate the effects of SBM and barley supplementation, at various levels of crude protein but the same amount of TDN, on eating and rumination behavior in sheep given rice straw as a basal diet.

Materials and Methods

Three Japanese Corriedale wethers (weighing 53.1 ± 1.5 kg) were used in a 3 × 3 latin square design. The sheep were kept in metabolism crates throughout the experimental periods and were fed rice straw supplemented with: ① 320 g barley (low crude protein, LCP), ② 235 g barley + 85 g SBM (medium crude protein, MCP) and ③ 150 g barley + 170 g SBM (high crude protein, HCP). All three supplements were formulated to contain the same amount of total digestible protein (TDN, 275 g) but varying levels of CP (40, 67 and 94 g for LCP, MCP and HCP, respectively). These supplements were chosen to supply approximately 40, 70 and 100% of CP and about 50% of the TDN requirements for maintenance of sheep weighing 50 kg (NRC, 1975). The RS was chopped into 1-2 cm length and offered *ad libitum*, i.e. 25% greater than the amount consumed on the previous day. The daily allowance of the RS and supplement were offered in two equal portions twice at 09:00 and 17:00 hrs, while the supplement was given just before feeding RS. The chemical composition of RS was 82.3% organic matter (OM), 3.6% CP, 73.8% neutral detergent fiber (NDF) and 55.5% acid detergent fiber (ADF). Soybean meal used in this study contained 93.1% OM and 44.3% CP; while barley contained 98.1% OM and 12.6 CP. The TDN content of SBM and barley was 86.8% and 86.4%, respectively (The standard chemical composition of Japanese feedstuff, 1980). Details of animal management and experimental procedures were the same as described in the previous study (Warly et al., 1992a). The characteristics of eating and rumination behavior were measured continuously for 5 consecutive days from records of jaw movement using a wire strain gauge held against the lower jaw of animal, according to the method of Harumoto and Kato (1978), while parameters of eating and rumination behavior were observed by the same method as reported earlier (Warly, et al., 1992b).

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

Results and Discussion

Table 1 shows voluntary intake of RS and activities of eating and rumination behavior for each treatment. The voluntary intake of RS was not affected by increasing level of protein supplementation, with average values of 603, 619 and 623 g/d for sheep fed LCP, MCP and HCP diets, respectively. The daily time spent eating rice straw was almost constant for all treatment diets, and consequently the eating rate of RS was not different among the treatments. However, the daily time spent ruminating decreased with increasing level of protein supplementation. Differences between LCP and HCP diets were significant ($p < 0.05$). When expressed per 100 g NDF intake, the time spent ruminating also decreased as supplementary protein level increased. Fujihara (1981) has used the rumination index (time spent ruminating per 100 g DM eaten) to evaluate the work done by ruminants in comminuting ingested diet. In the present study, the rumination index was greatly reduced by increasing level of supplemental protein, the average value being 90.7, 84.1 and 64.0 minutes for LCP, MCP and HCP diets, respectively.

Fujihara and Nakao (1984) have reported that the time spent eating hay by sheep was reduced but rumination index was not affected by an increased level of nitrogen supplementation with casein. In the present study, however, the increasing level of protein supplement did not affect the time spent eating RS, while rumination index significantly increased ($p < 0.05$). A result similar to the present study was obtained by Freer et al. (1962) where the time spent eating oat straw given *ad libitum* to cows was not affected by urea administration. These findings suggest that the differences in response to protein supplementation between the present study and the results of Fujihara and Nakao (1984) were probably caused by differences in physical and/or chemical

properties existing among the supplements and roughages used. According to Doyle (1987), response of ruminants to nitrogen supplement will be better when the CP content of forages is less than 7%. Fujihara and Nakao (1984) used a mixed hay containing 10.2% CP, while this study used RS contains 3.6% CP. Reduction in the time spent ruminating with increasing level of protein supplement, however, was consistent with the results of Fujihara and Nakao (1984) and Warly et al. (1992b). The fact that rumination index and rumination time per 100 g NDF intake were shortened by increasing protein level led to speculation that the main effect of protein supplementation was probably due to increasing number and activity of rumen microbial fermentation, thus the reduction of large particle size of digesta and its removal from the rumen was faster. These findings are also supported by the results reported earlier (Warly et al., 1992c) that rumen ammonia concentration, total volatile fatty acids (VFA_s) production and digestibility of NDF and ADF were significantly higher ($p < 0.05$) in sheep fed MCP and HCP diets than in those fed LCP diet. Harumoto and Kato (1979) suggested that changes in the rumination behavior of sheep fed RS supplemented with wheat bran were related to the changes in ruminal fermentation. In the second part of this experiment, Warly (1994) found that reduction in the proportion of large particle size (> 1.18 mm) over 24 hr after feeding was 23.0, 28.3 and 43.2% for LCP, MCP and HCP diets, respectively. Total mean retention time of digesta in the gastrointestinal tract reduced from 59.3 to 55.0 and 46.7 hr in sheep fed LCP, MCP and HCP diets, respectively. Rate of passage of digesta through the reticulo-rumen was highest in sheep fed HCP diet (6%/hr) than in those fed LCP and MCP diets (4.26 and 4.00%/hr, respectively). These findings imply that the higher reduction of large particle proportion in sheep fed HCP diet could be attributed to more vigorous attack of rumen microbes on the fibrous components, thus enhancing the passage rate of digesta through the reticulo-rumen. According to Sekine et al. (1992), decrease in proportion of particles larger than 1.18 mm in the rumen with time after feeding may be due to particle size reduction through microbial reduction and through a physical process such as mastication. However, it is not clear why the voluntary intake of rice straw was not different among treatments. The failure of increasing level of protein supplementation to stimulate intake of RS has probably been caused by a large amount of supplement offered (320 g/d).

TABLE 1. EFFECT OF VARYING LEVELS OF BARLEY AND SOYBEAN MEAL SUPPLEMENTATION ON EATING AND RUMINATION ACTIVITIES

Item	LCP	MCP	HCP	SEM*
Rice straw intake (g DM/d)	603.1	619.1	622.9	70.3
Total time spent eating rice straw (min/d)	257.1	273.1	263.1	32.6
Rate of eating rice straw (g DM/min)	2.4	2.3	2.4	0.1
Time spent ruminating :				
(min/d)	547.2[a]	520.6[ab]	398.8[b]	41.4
(min/100 g NDF intake)	104.1[a]	98.6[a]	76.2[b]	4.9
Rumination index*	90.7[a]	84.1[ab]	64.0[b]	4.1

[a,b] Values in the same row with different superscripts differ significantly ($p < 0.05$).
* Standard error of a mean.
* Time spent ruminating (min) per 100 g DM of RS intake.

Table 2 shows effect of varying levels of barley supplementation on characteristics of rumination behavior. The daily number of rumination periods was not significantly different among the treatments, supporting the suggestion of Harumoto and Kato (1978) that the number of rumination periods is a relatively stable parameter in the rumination behavior of sheep, which is not affected by different levels and kinds of feed. The length of each rumination period and number of boli per rumination period were also not affected by increasing level of protein supplemen-

tation. Similar results were obtained by Fujihara and Nakao (1984) and Warly et al. (1992b).

Although no significant differences were observed, the daily number of boli regurgitated was reduced from 555 and 553 boli in sheep fed LCP and MCP diets to 429 boli in those fed HCP diet. The latter value was relatively smaller than the result of the previous study (Warly et al., 1992a) when RS was supplemented with SBM alone. Cyclic rate, which is defined as daily time spent ruminating per number of boli regurgitated (Gordon, 1955) was almost constant for all the treatments, suggesting that the ruminal contraction was not affected by any supplementation, as proposed by Balch (1952). The bolus time which is the average time spent chewing each bolus was not significantly different among treatments, with average values of 48.2, 44.1 and 48.8 seconds per bolus. The number of chews per bolus and rate of chewing during rumination were not significantly different among treatments, corroborating the results of Fujihara and Nakao (1984). These findings suggest that the intensity of rumination was the same for all the treatments.

TABLE 2. EFFECT OF VARYING LEVELS OF BARLEY AND SOYBEAN MEAL SUPPLEMENTATION ON CHARACTERISTICS OF RUMINATION BEHAVIOR

Item	LCP	MCP	HCP	SEM
Daily no. of rumination periods	22.3	26.2	18.3	2.9
Duration of a rumination period (min)	23.7	21.0	23.7	3.4
No. of boli per rumination period	24.1	22.2	25.7	3.1
Daily no. of boli regurgitated	554.9	553.1	428.5	53.4
Cyclic rate[1]	59.2	56.6	55.7	1.2
Bolus time (sec)	48.2	44.1	48.8	3.3
No. of chews per bolus	56.7	50.3	56.5	1.6
Rate of chewing (chews/min)	70.7	68.5	70.0	3.3

[1] Cyclic rate = Time spent ruminating (sec) per daily number of boli regurgitated (Gordon, 1955).

Finally, it can be concluded that the characteristic rumination behavior in sheep fed a rice straw based diet was altered by increasing level of protein supplement made from a mixture of barley and soybean meal, when TDN of the supplement was maintained at 50% of the TDN requirement for maintenance of sheep. This alteration may closely be related to the improvement of ruminal conditions which could be associated with improvements in digestibility, reduction of rumen digesta particle size and passage rate of digesta. However, to further clarify the effects of nitrogen and energy supplementation on the rumination behavior in sheep given a rice straw based diet, further study using pure nitrogen and energy sources is necessary.

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