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Rumen Fermentation in Beef and Buffalo Steers Fed Native or Treated Rice Straw

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Abstract: The objective of this study was to compare the influence of grinding and/or urea-treatment of rice straw on fiber utilization in cattle and buffalo. Rumen-fistulated beef and buffalo steers were fed rations containing native rice straw, ground rice straw or urea-treated, ground rice straw and apparent fiber digestibility and rumen fluid characteristics were measured. Group-mean intake of roughage was enhanced in the beef steers fed urea-treated, ground rice straw but this was not seen in the buffaloes. Group-mean apparent digestibility of neutral and acid detergent fiber was raised by the feeding of urea-treated, ground rice straw versus ground rice straw in cattle. In the buffaloes, group-mean fiber digestibility was higher for urea-treated, ground rice straw than for native or ground rice straw. The apparent digestibility of crude protein was systematically lower in buffalo than in cattle. There was no effect of type of roughage on ruminal pH but the values were lower in buffalo than in cattle. Group-mean ruminal ammonia concentrations were higher in buffalo than in beef steers. The ruminal concentrations of acetate and propionate were significantly lower in buffalo than in cattle but the group-mean concentrations of butyrate were higher. The numbers of cellulolytic and amylolytic bacteria were markedly lower in the rumen fluid from buffalo than cattle. It is concluded that the present data do not allow a straightforward conclusion as to treatment of rice straw improving its utilization more in cattle or buffalo.

Key words: Rice straw, urea treated rice straw, rumen fermentation, apparent digestibility, beef cattle, buffalo

INTRODUCTION

In Thailand, the agricultural by product rice straw is commonly used as roughage source for the feeding of cattle and buffalo. The nutritive value of rice straw is low but its utilization can be improved by physical and chemical treatments (Borhami and Sundstol, 1982). Grinding of rice straw may enhance intake by ruminants (Wanapat *et al*. 2009) through stimulation of the passage rate and lowering of rumen retention time (Saadullah *et al*., 1981).

In ruminants, urea treatment has been shown to raise the nutritive value of rice straw (Sundstol *et al*., 1979; Wanapat *et al*., 1985) through an increase in digestibility and intake (Wanapat *et al*., 1985; Chemjong, 1991; Hart and Wanapat, 1992). Four studies carried out in India have shown that buffaloes digest crude fiber more efficiently than do cattle (Franzolin, 1994). However, as to the digestibility of neutral and acid detergent fiber the results of different studies are at variance (Franzolin, 1994). Calabro *et al*. (2008) have carried out *in vitro* studies with rumen fluid incubated with common feedstuffs for ruminants. It was found that gas production was lower for inoculum derived from buffalo than for samples from the rumen of cattle. Grant *et al*. (1974) measured *in vitro* true dry matter digestibility and concluded that there was no difference between rumen fluid from cattle and buffalo. Thus, the species difference seen in *in vivo* digestibility cannot be explained by differences in rumen fluid. The aim of the present study was to describe the influence of treatment of rice straw on its utilization in buffalo and cattle. We compared rumen fermentation in beef cattle and buffalo fed native rice straw, ground rice straw or urea-treated, ground rice straw. The steers used were fitted with a rumen fistula. Apparent whole-digestive tract digestibility of neutral and acid detergent fiber was used as an index of rumen fermentation. In addition, various characteristics of rumen fluid were used to assess the effects of type of rice straw and ruminant species on rumen fermentation.

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MATERIALS AND METHODS

Animals, design and diets: Three male beef steers (average body weight = 205 kg) and three male buffalo steers (average body weight = 290 kg) fitted with a rumen fistula were fed three different rations according to a 3×3 Latin-square design. Each feeding period lasted 21 days. During the first 14 days, feed intake was measured. Then the animals were kept in metabolism crates for 7 days. Feces were collected quantitatively during the last 5 days of each feeding period.

The rations consisted of roughage and concentrate. Three types of roughage were used: native Rice Straw (RS), Ground Rice Straw (GRS) and urea-treated, Ground Rice Straw (UGRS). The rice straw was ground to a particle size of 2-3 cm. Urea treatment involved the incubation of rice straw with an equal weight of water containing 5% urea for 21 days. Table 1 shows the analyzed composition of the three types of roughage and the concentrate.

The ingredient composition of the concentrate was as follows (g 100^{-1} g): cassava chips, 56.61; soybean meal, 7.79; cotton seed, 11.4; rice bran, 13.0; molasses, 8.0; urea, 1.4; dicalcium phosphate, 0.5; premix, 0.5; sulfur, 0.2; salt, 0.6. The animals had free access to the roughages and the concentrate. Any feed left-overs were measured daily.

Chemical analyses: Feed samples were collected weekly and pooled for analysis. Feed and feces samples were dried at 60°C for 72 h, ground and analyzed for dry matter, crude protein, ash, Neutral Detergent Fiber (NDF) and Acid Detergent Fiber (ADF) as described earlier (Jansen *et al.*, 2000). Macronutrient digestibility was expressed as percentage of intake and calculated as (nutrient intake-nutrient in feces) x nutrient intake^{-1} × 100.

At the end of each feces collection period, rumen samples were collected through the fistula at 4 h post feeding. The pH of rumen samples was measured immediately. Rumen fluid samples of 20 mL were acidified with 2 mL of 6 N HCl to inhibit microbial activity. The mixture was centrifuged at 16,000×g for 15 min and the supernatant was stored at -20°C prior to ammonia-N measurement (Bremner and Keeney, 1965) and the analysis of volatile fatty acids analysis using HPLC as described by Samuel *et al.* (1997). The number of cellulolytic and amylolytic bacteria was determined by the method of Purser and Moir (1966).

Statistical analysis: Data are reported as means and SEM for three beef and three buffalo steers. The data were subjected to ANOVA to identify statistically significant effects of type of rice straw and ruminant species. The LSD test was used to compare group means between dietary treatments within each species. The level of statistical significance was pre-set at $p<0.05$.

Table 1: Analyzed composition of the three types of roughage and concentrate

	Type of roughage			
Composition	RS	GRS	UGRS	Concentrate
Dry matter, percentage of product	92.6	92.8	52.7	87.5
Organic matter, percentage of DM	89.1	89.4	88.3	93.7
Crude protein, percentage of DM	3.57	3.32	5.86	12.7
Neutral detergent fiber, percentage of DM	73.7	74.7	74.8	22.3
Acid detergent fiber, percentage of DM	44.5	44.5	43.3	43.7
Ash, percentage of DM	10.9	10.6	11.7	6.3

DM = Dry Matter; RS = Rice Straw; GRS = Ground Rice Straw; UGRS = Urea-treated, Ground Rice Straw

RESULTS

Table 1 shows the analyzed composition of the three types of rice straw and the concentrate. Native and ground rice straw had similar compositions. The urea-treated rice straw contained almost 50% water, whereas the dry matter fraction was enriched with crude protein.

The buffalo steers consumed less roughage than did the beef steers which was apparent as absolute dry matter intake or expressed as either percentage of body weight or per kg of metabolic weight (Table 2). A similar species effect was seen for the intake of concentrate, expect when expressed as g per kg of metabolic body weight. In both cattle and buffalo, consumption of native rice straw was highest and ground rice straw lowest but the effect of type of roughage was statistically significant in buffalo only. Concentrate intake was not affected by the type of rice straw.

The apparent digestibility of dry matter oeganic matter, neutral detergent and acid detergent fiber was not significantly influenced by ruminant species and type of rice straw (Table 3). Group-mean digestibility of neutral and acid detergent fiber was greater in buffalo than in cattle for the feeding of ground rice straw or urea-treated, ground rice straw but not for native rice straw. In cattle, group-mean digestibility of ground rice and urea-treated, ground rice straw was lower than that of native rice straw. In the buffalo steers, the apparent digestibility of urea-treated, ground rice straw was higher than that of native or ground rice straw.

The apparent digestibility of crude protein was systematically lower in the buffalo steers than in the beef steers (Table 3). The type of rice straw did not affect crude protein digestibility in the beef steers but in their buffalo counterparts it was increased when they were fed urea-treated, ground rice straw.

Table 2: Intake of roughage and concentrate by beef and buffalo steers fed the experimental rations

Factors	Type of roughage RS	GRS	UGRS	SEM	p-value Ration	Species
Roughage intake						
kg DM						
Cattle	5.30	4.30	5.60	1.20	-	-
Buffalo	3.10[a]	1.80[b]	2.60[ab]	0.10	0.03	0.01
Percentage of BW						
Cattle	1.30	1.01	1.42	0.25	-	-
Buffalo	1.25[a]	0.75[c]	1.02[b]	0.04	0.04	0.06
g kg^{-1} MBW						
Cattle	56.10	44.60	60.50	10.60	-	-
Buffalo	49.50[a]	29.50[b]	41.10[a]	1.61	0.03	0.01
Concentrate intake						
kg DM						
Cattle	5.00	5.30	5.20	0.54	-	-
Buffalo	3.50	3.40	3.30	0.05	0.88	0.01
Percentage of BW						
Cattle	1.17	1.22	1.23	0.03	-	-
Buffalo	1.42	1.35	1.26	0.04	0.5	0.01
g kg^{-1} MBW						
Cattle	53.20	55.50	55.70	0.05	-	-
Buffalo	56.30	53.70	51.80	0.13	0.79	0.51
Total DM intake (kg)						
Cattle	10.30	9.60	10.80	1.60	-	-
Buffalo	6.60[a]	5.30[b]	6.00[ab]	0.14	0.06	0.01
Percentage of BW						
Cattle	2.40	2.19	2.560	0.21	-	-
Buffalo	2.67	2.10	2.280	0.08	0.05	0.76
g kg^{-1} MBW						
Cattle	109.20	100.10	116.20	10.20	-	-
Buffalo	105.80[a]	83.20[b]	92.80[ab]	2.70	0.04	0.01

BW = Body Weight; MBW = Metabolic Body Weight (kg$^{0.75}$); DM = Dry Matter; RS = Rice Straw; GRS = Ground Rice Straw; UGRS = Urea-treated, Ground Rice Straw. Means within a row and within species with different superscript letter are significantly different

Table 3: Apparent digestibility of macronutrients in beef and buffalo steers fed the experimental rations

Digestibility of macro nutrient	Type of roughage RS	GRS	UGRS	SEM	p-value Ration	Species
DM (Percentage of intake)						
Cattle	69.4	63.7	67.2	2.82	-	-
Buffalo	67.0	68.7	72.8	1.57	0.35	0.20
Organic matter (percentage of intake)						
Cattle	72.0	66.8	70.0	2.42	-	-
Buffalo	70.4	71.8	75.5	1.48	0.34	0.14
Crude protein (percentage of intake)						
Cattle	71.9	70.2	72.2	0.92	-	-
Buffalo	64.0[b]	64.5[b]	68.9[a]	0.45	0.24	0.01
Neutral detergent fiber (percentage of intake)						
Cattle	55.0	41.4	53.3	7.15	-	-
Buffalo	49.5	49.9	60.4	3.16	0.10	0.39
Acid detergent fiber (percentage of intake)						
Cattle	53.5	37.3	50.5	9.24	-	-
Buffalo	46.6	46.8	52.9	3.13	0.16	0.67

DM = Dry Matter; RS = Rice Straw; GRS = Ground Rice Straw; UGRS = Urea-treated, Ground Rice Straw. Means within a row and within species with different superscript letter are significantly different

There was no effect of type of roughage on ruminal pH but the values were systematically lower in buffalo than in cattle (Table 4). Group mean ruminal ammonia concentrations were higher in buffalo than in beef steers. In the buffalo steers, ruminal ammonia concentrations were significantly increased after the feeding of urea-treated, ground rice straw instead of either native or ground rice straw. The ruminal concentrations of acetate and propionate were significantly lower in buffalo than in cattle (Table 3). In contrast, the group-mean concentrations of butyric acid were higher in the buffalo steers. There was a substantial but non-significant increase in ruminal acetate in the beef steers when they were fed ground rice straw. The feeding of ground rice to the buffalo steers raised the concentration of propionate in rumen fluid.

The numbers of cellulolytic and amylolytic bacteria were markedly lower in the buffalo versus the beef steers (Table 3). In the buffaloes, the feeding of ground rice straw induced a significant decrease in the amount of amylolytic bacteria when compared with the rations containing either native rice or urea-treated, ground rice.

Table 4: Indicators of rumen function in beef and buffalo steers fed the experimental rations

Items	Type of roughage RS	GRS	UGRS	SEM	p-value Ration	Species
Ruminal pH						
Cattle	6.84	6.64	6.78	0.05		
Buffalo	6.56	6.47	6.38	0.03	0.55	0.03
Ruminal ammonia (mg N 100 mL^{-1})						
Cattle	5.75	7.24	9.04	1.38		
Buffalo	7.99[b]	8.29[b]	16.36[a]	0.32	0.07	0.03
Cellulolytic bacteria (10^{7} x CFU mL^{-1})						
Cattle	5.53	6.03	8.78	1.49		
Buffalo	0.66	0.63	0.66	0.04	0.22	0.01
Amylolytic bacteria (10^{5} x CFU mL^{-1})						
Cattle	8.90	7.36	10.30	3.01		
Buffalo	1.09[a]	0.65[b]	1.07[a]	0.05	0.56	0.01
Acetate (%)						
Cattle	66.20	63.80	70.10	2.00		
Buffalo	56.10	53.20	56.10	2.32	0.56	0.05
Propionate (%)						
Cattle	19.70	22.10	19.40	2.48		
Buffalo	19.90[b]	23.50[a]	20.00[b]	0.18	0.97	0.01
Butyrate (%)						
Cattle	14.10	14.10	10.50	0.48		
Buffalo	23.60	23.30	23.90	2.26	0.94	0.18

RS = Rice Straw; GRS = Ground Rice Straw; UGRS = Urea-treated, Ground Rice Straw. Means within a row and within species with different superscript letter are significantly different

DISCUSSION

Total dry matter intake expressed as g per kg metabolic weight was lower in the buffalo steers than in the beef steers when the ration contained ground rice straw or urea-treated ground rice straw. The species difference in total feed intake was mainly caused by the lower intake of roughage by the buffalo steers. The data point at a higher feed efficiency in buffalo. Indeed, the general consensus is that buffaloes utilize poor quality fibrous feed more efficiently than do beef steers and cows (Grant *et al.*, 1974; Franzolin, 1994; Calabro *et al.*, 2008). In the ruminal fluid from the buffalo steers markedly lower numbers of cellulolytic and amylolytic bacteria were found than in rumen fluid from the beef steers. In two earlier studies, larger numbers of cellulolytic bacteria were found in buffalo rumen than in cattle rumen (Sadhana *et al*., 1992; Malakar and Walli, 1995). In those two studies, the two ruminant species were fed rations consisting of wheat straw and concentrate. It is possible that an interaction between ruminant species and composition of the ration determines the number of cellulolytic bacteria in ruminal fluid.

The low number of amylolytic bacteria in the rumen of buffalo steers agrees with the low ruminal concentration of propionate which is the main product of starch degradation. In this study, the type of rice straw did not influence the number of cellulolytic bacteria in both the beef and buffalo steers. In the buffalo steers but not the beef steers, the feeding of ground rice straw significantly reduced the number of amylolytic bacteria but it raised the ruminal concentration of propionate. This outcome points at a discrepancy which cannot be readily explained.

The apparent total intestinal tract digestibility of neutral and acid detergent fiber was not systematically higher in buffalo than in cattle. This outcome agrees with the general picture based on nine different studies that were reviewed by Franzolin (1994). In those nine studies, the apparent digestibility of neutral and acid detergent fiber was lower, higher of not different in buffaloes when compared with cattle. The lack of species effect on fiber digestibility in this study does not agree with the lower ruminal pH and lower acetate concentrations in the buffaloes. Moreover, the lower ruminal pH values associated with lower acetate concentrations in the buffalo versus beef steers can be considered as a contradiction. Clearly, the data on digestibility of fiber and rumen milieu cannot be reconciled. This is supported by earlier studies, leading to the conclusion that species difference seen in *in-vivo* digestibility cannot be explained by differences in rumen fluid (Grant *et al*., 1974; Franzolin, 1994; Calabro *et al*., 2008).

The type of rice straw did not significantly affect the apparent digestibility of neutral and acid detergent fiber but there were large differences in the group-mean values. In the beef steers, the fiber digestibility was lowered by the feeding of ground rice straw instead of native rice straw. Contrary to the expectation based on earlier research (Sundstol *et al*., 1979; Wanapat *et al*., 2009), urea-treated, ground rice straw versus native rice straw did not enhance fiber digestibility in the beef steers. However, when compared with ground rice straw, urea treatment markedly raised group-mean digestibility of neutral and acid detergent fiber in the beef steers. In the buffalo steers, urea treatment raised the group-mean digestibility of neutral detergent fiber and to a lesser extent that of acid detergent fiber. When the buffalo steers were fed native or ground rice straw, the digestibilities of neutral and acid detergent fiber were similar. The apparent digestibility of crude protein was significantly lower in the buffalo steers than in the beef steers. This species difference was associated with higher ruminal ammonia concentrations in the buffaloes. In 6 earlier studies, apparent digestibility of crude protein was either higher or not different in buffaloes when compared with cattle (Franzolin, 1994). Ruminal ammonia concentrations were higher in buffaloes in 6 out of 8 studies (Franzolin, 1994). The higher ruminal ammonia concentrations found in the buffalo steers point at low bacterial protein synthesis in the rumen which corroborates the low numbers of ruminal bacteria.

This could be caused by the relatively high protein supply in this study. At least on low-protein diets, buffaloes show higher microbial protein synthesis than do cattle (Franzolin, 1994). The observed low digestibility of crude protein in the buffalo steers might relate to a lower maximum capacity of protein digestion in the small intestine.

CONCLUSION

The urea-treated, ground rice straw contained more crude protein than native or ground rice straw. This difference can be explained by the addition of nitrogen in the form of urea. The higher urea content of the ration with urea-treated rice straw most likely caused the higher group-mean ruminal ammonia concentrations in both the buffalo and beef steers. The increase in ruminal ammonia was greater in the buffaloes which would agree with a lesser utilization of nitrogen due to a lower microbial protein synthesis. When the buffaloes were fed urea-treated rice straw, apparent protein digestibility was increased when compared with the feeding of either native or ground rice straw. This increase in apparent crude protein digestibility can be explained by the ruminal uptake of ammonia not used for microbial protein synthesis.

The objective of this study was to find out whether the improvement of utilization of rice straw through grinding or urea treatment would be different in buffalo and cattle. Group-mean intake of roughage was enhanced in the beef steers fed urea-treated rice straw but this was not seen in the buffaloes. This could be interpreted as urea treatment being less effective in the buffaloes. Grinding plus urea treatment of rice straw numerically raised the apparent digestibility of neutral and acid detergent fiber in the buffalo steers but not in the beef steers. This could be interpreted as urea treatment being more effective in the buffaloes. Thus, the present study does not allow a straightforward conclusion.

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