EFFECTS OF HIGH BY-PRODUCT DIETS CONTAINING RICE BRAN AND BEET PULP ON THE SITE AND EXTENT OF DIGESTION AND MICROBIAL SYNTHESIS IN STEERS

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Summary

The effects of feeding rice bran and beet pulp mixtures on the site and extent of digestion and microbial synthesis in fattening steers were studied. Three Holstein steers fitted with ruminal, duodenal and ileal cannulas were fed four diets in a 4 × 3 Youden square design. The four diets consisted of 15% Italian ryegrass hay and 85% concentrate as a control diet which included 72% rolled barley, 20% rice bran plus 40% beet pulp, 30% rice bran plus 30% beet pulp or 40% rice bran plus 20% beet pulp. All diets provided 1.8 times digestible energy required for maintenance. The digestibility of fat in the small intestine (% of flow) showed an increase with rice bran content among the by-product diets. Digestibility of structural carbohydrate both in the rumen and the whole digestive tract decreased linearly with rice bran content. The digestibility of nonstructural carbohydrate was not affected by rice bran content, but that of nonstructural, nonstarch polysaccharides was higher in the rumen and lower in the large intestine for the by-product diets than for the control diet. A rice bran content of more than 30% in the by-product diets severely inhibits ruminal microbial synthesis and digestible energy intake in fattening steers.
(**Key Words** : Rice Bran, Beet Pulp, Steers, Carbohydrate Digestion, Microbial Synthesis)

Introduction

The demand for livestock products in Asia has increased rapidly with economic development. However, the production of grain in this region is inadequate to support its livestock production, so the effective use of various by-products for replacing grain in livestock production is desirable.

Rice bran is a high energy by-product, rich in fat and starch, and its annual production reaches 40-45 million tons in the far-east and south-east Asia (Farrell, 1994). In ruminant diets, however, the use of rice bran may be restricted because excessive supplementation of lipids from vegetable sources reduces fiber digestion (Devendra and Lewis, 1974). In addition, we recently reported that a diet containing 30% full-fat rice bran decreased digestion of fiber, but not of nonstructural carbohydrate (NSC) in the rumen (Zhao et al., 1996). Among the by-products, dry matter (DM) from beet pulp is extremely degradable in the rumen (Nocek and Russell, 1988) because the fiber and pectin in the beet pulp are readily fermentable (Tanaka et al., 1993). However, there are few reports on the influence of lipids on beet pulp digestion.

Our objectives were to investigate the effects of the mixtures of rice bran and beet pulp on the site and extent of digestion of carbohydrate fraction and nitrogen (N) utilization in the digestive tract of steers, and to ascertain the most appropriate proportion of rice bran in a high by-product diet for fattening cattle.

Materials and Methods

Animals and diets

Three Holstein steers were used in a 4 × 3 Youden square design with 21-day periods. They weighed 434 ± 12.6 kg at the beginning of the experiment. They were fitted with a permanent ruminal cannula and T-shaped cannulas with a gutter-type base at the proximal duodenum and terminal ileum (Taniguchi and Obitsu, 1994). The animals were housed in individual stanchions (1.4 m × 2.0 m space per head) with rubber mats in a well-ventilated room, provided with free access to water.

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The control diet consisted of 15% Italian ryegrass hay, 72 % rolled barley and other supplements. By-product diets were formulated using 15% Italian ryegrass hay in all treatments, together with 20% rice bran plus 40% beet pulp for a low rice bran-high beet pulp treatment (LRHB), 30% rice bran plus 30% beet pulp for a medium rice bran-beet pulp treatment (MRMB), 40% rice bran plus 20% beet pulp for a high rice bran-low beet pulp treatment (HRLB). All diets were designed to be equal in crude protein (CP; 12%). The ingredients and chemical composition of the diets is shown in tables 1 and 2. Since the heat processing of rice bran can extend its storage life, and did not differ in its site and extent of digestion compared with raw rice bran (Zhao et al., 1996), we used heated rice bran in this study. Each diet was fed to provide 1.8 times maintenance energy requirement (Agriculture, Forestry and Fisheries Research Council Secretariat, 1987). The animals were provided with their diets in two equal meals given at 09:00 and 18:00. At each feeding time, a gelatin capsule containing 3 g chromic oxide was inserted in the rumen via the rumen cannula.

TABLE 1. INGREDIENTS OF THE EXPERIMENTAL DIETS ON A DRY MATTER BASIS (%)

Item	Diet[1]			
	Control	LRHB	MRMB	HRLB
Italian ryegrass	15.0	15.0	15.0	15.0
Rolled barley	71.9	11.6	13.3	15.0
Heated rice bran	–	20.0	30.0	40.0
Beet pulp	–	40.0	30.0	20.0
Soybean meal	6.6	6.9	5.2	3.5
Tricalcium phosphate	3.2	2.4	1.2	–
Calcium carbonate	0.6	1.4	2.6	3.8
Sodium chloride	0.7	0.7	0.7	0.7
Mineral/vitamin pre-mix[2]	2.0	2.0	2.0	2.0

[1] LRHB, 20% heated rice bran + 40% beet pulp; MRMB, 30 % heated rice bran + 30% beet pulp; HRLB, 40% heated rice bran + 20% beet pulp.

[2] Each kilogram of mineral/vitamin pre-mix contained the following: $MgSO_4$, 173.4 g; $MgCO_3$, 18.5 g; $MnCO_3$, 1.0 g; $ZnCO_3$, 2.0 g; $CuSO_4$, 0.3 g; Ca $(IO_3)_2$, 77 mg; $CoSO_4$, 27 mg; Vitamin A, 1,200,000 IU; Vitamin D_3, 200,000 IU; Vitamin E, 1.0 g.

TABLE 2. CHEMICAL COMPOSITION OF THE EXPERIMENTAL DIETS ON A DRY MATTER BASIS (%)

Item	Diet[1]			
	Control	LRHB	MRMB	HRLB
Dry matter[2]	86.8	88.2	88.6	85.1
Organic matter	92.3	89.5	89.8	89.1
Crude protein	12.5	11.9	12.2	12.5
Fat	2.0	6.0	8.7	10.8
Starch	39.4	11.1	12.3	14.5
Neutral detergent fiber	26.1	33.6	31.8	30.9
Acid detergent fiber	11.4	19.8	18.5	16.5
Nonstructural carbohydrate[3]	53.2	40.4	38.7	36.4

[1] LRHB, 20% heated rice bran + 40% beet pulp; MRMB, 30 % heated rice bran + 30% beet pulp; HRLB, 40% heated rice bran + 20% beet pulp.

[2] Percentage of air-dry matter.

[3] OM-crude protein-(NDF-NDF bound protein)-fat.

Sample collection

Each period in the Youden square consisted of 2 weeks for adaptation followed by 1 week for sample collection. Samples of diets, residues, intestinal contents and feces were collected on the first 4 days of each collection period. Samples from the duodenum (150 ml) and ileum (60 ml) and of feces (150 g) were collected over a 4-day period. The three sampling times were evenly spaced within each day, shifted forwards by 2 h each day to allow 1 sample to be collected during every 2 h of a 24 h period, for each animal and collection period. A portion of the duodenal contents was frozen at −20℃ for subsequent determination of ammonia N. The remaining duodenal, ileal and fecal samples were pooled separately for each steer within each collection period. The duodenal and ileal samples were later lyophilized, and the fecal samples were dried at 55℃ in a forced-air oven for 3 days. Samples of feed, residues, dried duodenal and ileal digesta and feces were ground to pass through a 1 mm screen prior to analysis.

On the day 5 of the collection period, samples of the ruminal contents (400 ml) were collected through the ruminal cannula at 0, 2 and 5 h after the morning feed. The pH of the samples was determined immediately using a glass electrode (HM-5B, Toa Electronics, Japan), and they were then filtered through a wire screen (35 mesh). A portion of the filtrate (50 ml) was transferred to a container with 1 ml H_2SO_4 (50% v/v) and was frozen at −20℃ for subsequent analysis. The remainder of the filtrate was pooled for each animal. Mixed ruminal bacteria was isolated from the pooled ruminal contents by differential centrifugation (Smith and McAllan, 1974), and they were then lyophilized for subsequent analysis.

In situ procedures

The disappearance of DM was determined *In situ* for Italian ryegrass hay and beet pulp for each steer and each diet. Five grams of air-dried hay and beet pulp, previously ground through a 2 mm screen, were weighed into polyster bags (14 cm × 16 cm; 48 μm pore size), respectively. Two 6 g steel balls were added to each bag as a weight. The bags were soaked in tap water for approximately 5 min, and then incubated in the rumen for 2, 4, 8, 16, 24, 36, or 48 h from the days four to six of each collection period. All bags were removed at the same time, and thoroughly rinsed with running tap water, and they were then dried at 55℃ in a forced-air oven for subsequent determination of DM weight.

Chemical analysis

Feeds, residues, dried duodenal and ileal digesta, bacterial composites, and feces were analyzed for DM, N and ash content (AOAC, 1975). Fat content was measured by the acid hydrolysis procedure (Sanderson, 1986). Gross energy content was determined using an adiabatic bomb calorimeter (CA-3, Shimadzu Seisakusho, Japan). Starch content was determined enzymatically (Herrera-Saldana and Huber, 1989), using heat-stable α-amylase (Sigma Chemical Co., St., Louis, MO) and amyloglucosidase (Sigma). The heat-stable α-amylase was also used for pre-treatment of samples for determination of neutral detergent fiber (NDF) content (Van Soest et al., 1991). The acid detergent fiber (ADF), acid detergent lignin and NDF contents were determined by the methods of Robertson and Van Soest (1981). The purines of bacterial isolates from the ruminal liquid and the duodenal digesta were determined by the method of Zinn and Owens (1986). The frozen samples of duodenal and ruminal contents were thawed at room temperature, centrifuged at 2,000 × g for 20 min, and the supernatant was analyzed for ammonia N (Okuda et al., 1965). The ruminal concentration of total volatile fatty acids (VFA) was determined by the gas-liquid chromatography (Taniguchi et al., 1991). The chromium content of the duodenal and ileal digesta and feces was determined by calorimetric procedures (Yoshida et al., 1967).

Calculations and statistical analysis

Nutrient flow at the duodenum and ileum and fecal output were calculated with reference to chromic oxide and nutrient concentrations. Cellulose and hemicellulose contents were calculated as the difference between ADF and acid detergent lignin, and as the difference between NDF and ADF, respectively. The NSC [OM-CP-(NDF-protein in NDF)-fat] and nonstructural nonstarch carbohydrate (NSP; NSC-starch) were calculated as described by Van Soest et al. (1991). Total carbohydrates (TCHO) were calculated as organic matter (OM) − (CP + fat). The three observations for the ruminal fermentation data were averaged by animal within each collection period for statistical analysis.

Statistical analysis was performed using the GLM procedure of the SAS (1990). Model sums of squares were separated into animal, period and treatment effects. Treatment comparisons on the parameters measured were carried out by orthogonal contrasts (Steel and Torrie, 1980) : 1) the linear effect of rice bran content in the by-product diets, and 2) the quadratic effect of rice bran content in the by-product diets. The significance of the differences between the control and by-product diets was evaluated using Dunnett's test (Steel and Torrie, 1980). Differences were considered to be significant if probability was equal to or less than 0.05.

Results

Intake

Less DM was given for the control and HRLB diets than for the LRHB and MRMB diets (table 3), since we intended to provide the same digestible energy (DE) in all of the diets. However, the actual DM intake for the by-product diets was not different to that of the control diet due to the residues. As for nutrient intake, by-product diets were lower in NSC and starch (table 6), but greater in fat (table 4), fiber (table 5) and NSP (table 6) compared with the control diet.

In vivo digestion

Digestibility of OM, TCHO (table 3), NDF, ADF, cellulose and hemicellulose (table 5) in the rumen decreased linearley with increasing rice bran level in the by-product diets. Compared with the control diet, ruminal digestibility of TCHO was higher for the LRHB diet, of NDF for LRHB and MRMB diets, and of ADF for all of the by-product diets. The digestibility of these fiber fractions in the whole digestive tract also showed similar tendencies among the by-product diets and between the control and by-product diets. The digestibility of NSC in the rumen was higher for the LRHB than the control diet (table 6). In the by-product diets, NSC digestibility in the rumen decreased quadratically with the rice bran level. The digestibility of NSP was not affected by rice bran content, but that of NSP was higher in the rumen and the whole digestive tract, and lower in the large intestine for the by-product diets than for the control deit. The digestibility of starch in each segment of the digestive

TABLE 3. INTAKE AND DIGESTION OF ENERGY, DRY MATTER, ORGANIC MATTER, AND TOTAL CARBOHYDRATE IN EACH SEGMENT OF THE DIGESTIVE TRACT OF STEERS FED ON MIXED BY-PRODUCT DIETS

Item	Diet[1]				SEM[3]	Contrasts[2], (P)	
	Control	LRHB	MRMB	HRLB		L	Q
Dry matter							
Supply (g day⁻¹)	7,079	7,406**	7,299**	6,840**	10.7	0.01	0.04
Intake (g day⁻¹)	7,079	7,269	7,141	6,701	161.1	0.21	0.60
Organic matter							
Intake (g day⁻¹)	6,351	6,500	6,400	5,946	162.7	0.23	0.59
Digested in the rumen							
Apparent (g day⁻¹)	3,781	4,457*	3,876	3,117*	112.7	0.05	0.57
Digestibility (% of intake)							
Apparent ruminal	57.9	68.6**	60.6*	52.4**	0.40	0.01	0.33
True ruminal	74.4	80.7**	73.7	63.8**	0.42	0.01	0.02
Small intestinal	15.9	6.6**	10.9**	12.6**	0.26	0.01	0.03
Large intestinal	7.0	3.1*	5.0	6.1	0.56	0.19	0.98
Total tract	80.8	78.2	76.4*	71.1**	0.49	0.07	0.29
Total carbohydrate							
Intake (g day⁻¹)	5,504	5,221	4,931	4,408**	105.7	0.10	0.60
Digested in the rumen							
Apparent (g day⁻¹)	3,865	4,100	3,594	3,001*	95.7	0.05	0.84
Digestibility (% of intake)							
Ruminal	70.2	78.5*	72.9	68.1	0.50	0.01	0.09
Small intestinal	5.7	1.0**	3.2*	1.8**	0.27	0.34	0.10
Large intestinal	6.0	2.4	4.4	5.8	0.73	0.27	0.95
Total tract	81.9	81.9	80.4	75.7**	0.57	0.11	0.40
Energy							
GE[4] intake (MJ day⁻¹)	133.7	138.3	140.4	136.1	4.18	0.75	0.80
Intended DE intake[5] (MJ day⁻¹)	100.2	99.6	100.2	99.9	0.27	0.58	0.07
Actual DE[6] intake (MJ day⁻¹)	103.2	103.0	99.6	90.0	2.66	0.21	0.65

[1] LRHB, 20% heated rice bran + 40% beet pulp; MRMB, 30% heated rice bran + 30% beet pulp; HRLB, 40% heated rice bran + 20% beet pulp.
[2] Linear (L) and quadratic (Q) effects of rice bran content.
[3] Standard error of the mean.
[4] Gross energy.
[5] Calculated from the Japanese Standard table of Feed Composition (1987).
[6] Digestible energy.
*$p < 0.05$; **$p < 0.01$ (different from control diet).

tract was not affected by the treatments.

Ruminal disappearance of fat was negative for the control diet, but that was positive for the by-product diets (table 4). In the by-product diets, when the rice bran level increased, the fat disappearance decreased, conversely, fat digestibility in the small intestine (percentage of flow) increased slightly and linearly. As a result, the fat digestibility in the whole digestive tract was not affected by the rice bran level. However, fat digestibility in the small intestine for these by-product diets was lower than that for the control, resulting in lower fat digestibility in the whole digestive tract.

Microbial synthesis and N utilization

Microbial N flow to the duodenum decreased linearly with rice bran level among the by-product diets (table 7). Compared with the control diet, by-product diets had lower duodenal microbial N flow and microbial efficiency. The digestibility of N in the small intestine (percentage of flow) and the whole digestive tract were lower for the by-

TABLE 4. INTAKE AND DIGESTION OF FAT IN EACH SEGMENT OF THE DIGESTIVE TRACT OF STEERS FED ON MIXED BY-PRODUCT DIETS

Item	Diet[1]				SEM[3]	Contrasts[2], (P)	
	Control	LRHB	MRMB	HRLB		L	Q
Intake (g day^{-1})	144	429**	604**	709**	23.7	0.06	0.54
Ruminal disappearance (g day^{-1})	−62.5	99.6**	120.1**	55.9**	10.01	0.23	0.24
Duodenal flow (g day^{-1})	206.2	328.9*	484.2**	653.0**	14.06	0.02	0.44
Ileal flow (g day^{-1})	50.2	224.9**	324.1**	389.9**	6.02	0.01	0.05
Fecal excretion (g day^{-1})	31.3	213.8**	293.0**	363.1**	12.14	0.08	0.85
Digestion (g day^{-1})							
Small intestinal	156.1	104.6	160.0	263.1*	13.94	0.04	0.21
Large intestinal	18.8	11.1	31.1	26.9	9.12	0.72	0.57
Digestibility							
% of flow							
Small intestinal	75.3	31.7**	33.0**	40.3**	2.14	0.01	0.02
Large intestinal	37.0	4.9*	9.5*	6.9*	4.43	1.00	0.62
% of intake							
Total tract	78.0	50.1**	51.5**	48.8**	1.45	0.29	0.41

[1] LRHB, 20% heated rice bran + 40% beet pulp; MRMB, 30% heated rice bran + 30% beet pulp; HRLB, 40% heated rice bran + 20% beet pulp.
[2] Linear (L) and quadratic (Q) effects of rice bran content.
[3] Standard error of the mean.
* $p < 0.05$; ** $p < 0.01$ (different from control diet).

product diets than for the control diet. The HRLB diet, which had the highest level of rice bran, showed the lowest nonammonia N flow to the duodenum and the lowest ruminal degradability of N.

Ruminal characteristics

The ruminal fermentation characteristics, expressed as daily means, are shown in table 8. The ruminal pH and ammonia N concentration did not differ among all the diets. Compared with the control diet, the LRHB diet was higher in total VFA concentration and its molar proportion of acetate. In the by-product diets, the total VFA concentration and molar proportions of acetate and n-butyrate decreased with the level of rice bran, but that of propionate ($p < 0.14$) tended to increase.

In situ disappearance

The *In situ* DM disappearances of beet pulp and hay are presented in figures 1 and 2, respectively. The DM disappearances of both beet pulp and hay showed similar patterns in the by-product diets, and were slightly higher than those for the control diet. At the 48 h incubation in the rumen, the DM disappearance for beet pulp and hay averaged 79.6% and 46.3%, respectively, in all the diets.

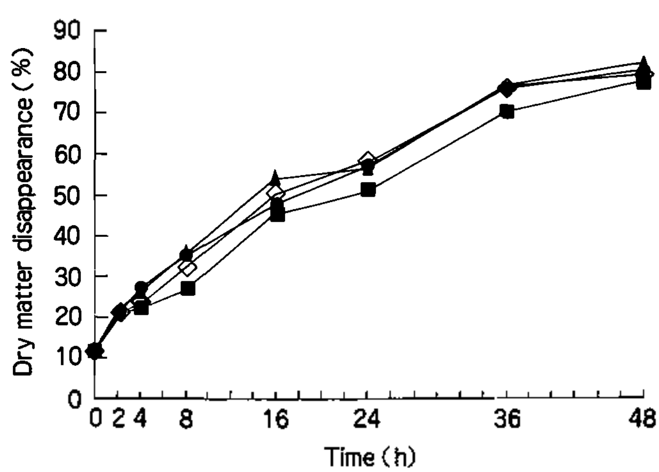

Figure 1. *In situ* (rumen) dry matter disappearance of beet pulp from control (■), LRHB (●), MRMB (◇) or HRLB (▲) diet. Standard error of means were 0.58, 1.11, 2.27, 7.54, 4.56, 2.10 and 3.54% for 2, 4, 8, 16, 24, 36 and 48 h of incubation, respectively.

Discussion

In the present study, an increase of 20 to 40% in the

TABLE 5. INTAKE AND DIGESTION OF NEUTRAL DETERGENT FIBER, ACID DETERGENT FIBER, HEMICELLULOSE AND CELLULOSE IN EACH SEGMENT OF THE DIGESTIVE TRACT OF STEERS FED ON MIXED BY-PRODUCT DIETS

Item	Diet[1]				SEM[3]	Contrasts[2], (P)	
	Control	LRHB	MRMB	HRLB		L	Q
Neutral detergent fiber							
Intake (g day⁻¹)	1,843	2,440**	2,286**	2,097*	35.0	0.08	0.84
Digested in the rumen							
Apparent (g day⁻¹)	948	1,641**	1,378**	1,017*	9.9	0.01	0.12
Digestibility (% of intake)							
Ruminal	51.4	67.2**	60.3**	48.5	0.53	0.01	0.07
Post-ruminal	2.8	1.3	1.2	3.0	0.69	0.03	0.03
Total tract	54.2	68.6**	61.4**	51.5	0.58	0.01	0.17
Acid detergent fiber							
Intake (g day⁻¹)	803	1,441*	1,325*	1,123*	17.1	0.03	0.22
Digested in the rumen							
Apparent (g day⁻¹)	347	973**	817**	602**	5.8	0.01	0.08
Digestibility (% of intake)							
Ruminal	43.2	67.5**	61.7**	53.6**	0.35	0.03	0.27
Post-ruminal	2.2	1.6	1.1	0.6	0.73	0.54	0.78
Total tract	45.4	69.1**	62.8*	54.2*	0.70	0.04	0.27
Hemicellulose							
Intake (g day⁻¹)	1,040	1,000	962	974	35.8	0.95	0.63
Digested in the rumen							
Apparent (g day⁻¹)	601	667*	561	414**	10.5	0.04	0.31
Digestibility (% of intake)							
Ruminal	57.8	66.8*	58.3	42.6**	1.03	0.04	0.18
Post-ruminal	3.2	1.0	1.1	5.9	2.14	0.23	0.25
Total tract	61.0	67.8	59.4	48.4*	1.82	0.03	0.57
Cellulose							
Intake (g day⁻¹)	660	1,257**	1,026**	911**	30.1	0.01	0.04
Digested in the rumen							
Apparent (g day⁻¹)	404	1,000**	774**	674**	6.8	0.01	0.04
Digestibility (% of intake)							
Ruminal	61.2	79.5**	75.5*	74.0*	1.70	0.28	0.62
Post-ruminal	2.9	5.5	2.3	1.2	2.07	0.44	0.86
Total tract	64.1	85.1**	77.8**	75.2**	0.89	0.13	0.44

[1] LRHB, 20% heated rice bran + 40% beet pulp; MRMB, 30% heated rice bran + 30% beet pulp; HRLB, 40% heated rice bran + 20% beet pulp.
[2] Linear (L) and quadratic (Q) effects of rice bran content.
[3] Standard error of the mean.
*$p < 0.05$; **$p < 0.01$ (different from control diet).

level of rice bran in the by-product diets elevated the dietary fat content from 6 to 11%, and fat digestibility in the small intestine (percentage of flow) ranged from 31.7 to 40.3%. In our previous study (Zhao et al., 1996), when the diet contained 30% raw or heated rice bran, the fat digestibility in the small intestine was also low (approximately 46%). Doreau and Ferlay (1994) in their review have indicated that intestinal digestibility of fatty acids is not related to the fatty acid intake, and the mean digestibility in various sources is 77%, although Palmquist and Jenkins (1980) reported that when fatty acids formed in excess of 5 to 6% of the diet, the fatty acids were

TABLE 6. INTAKE AND DIGESTION OF NONSTRUCTURAL CARBOHYDRATE, STARCH AND NON STARCH POLYSACCHARIDES IN EACH SEGMENT OF THE DIGESTIVE TRACT OF STEERS FED ON MIXED BY-PRODUCT DIETS

Item	Diet[1]				SEM[3]	Contrasts[2], (P)	
	Control	LRHB	MRMB	HRLB		L	Q
Nonstructural carbohydrate[4]							
Intake (g day^{-1})	3,748	2,943**	2,758**	2,408**	73.4	0.11	0.66
Digested in the rumen							
Apparent (g day^{-1})	2,953	2,579	2,276*	2,020**	86.9	0.10	0.52
Digestibility (% of intake)							
Ruminal	78.8	87.6*	82.5	83.8	1.10	0.10	0.05
Small intestinal	6.5	1.1	4.3	1.9	0.94	0.83	0.19
Large intestinal	8.8	3.4	7.4	6.6	1.12	0.44	0.47
Total tract	94.1	92.1	94.2	92.4	0.69	0.80	0.37
Starch							
Intake (g day^{-1})	2,794	800**	863**	954**	28.8	0.08	0.35
Digested in the rumen							
Apparent (g day^{-1})	2,571	731**	785**	875**	37.7	0.07	0.26
Digestibility (% of intake)							
Ruminal	92.0	91.3	91.0	91.7	0.35	0.43	0.25
Small intestinal	7.5	7.9	8.7	7.5	0.41	0.02	0.01
Large intestinal	0.4	0.6	0.2	0.7	0.14	1.00	0.33
Total tract	99.9	99.9	99.8	99.9	0.02	0.37	0.29
Nonstarch polysaccharides[5]							
Intake (g day^{-1})	954	2,190**	1,977**	1,442**	44.5	0.05	0.21
Digested in the rumen							
Apparent (g day^{-1})	382	1,895**	1,573**	1,132**	64.8	0.04	0.51
Digestibility (% of intake)							
Ruminal	39.6	86.5**	79.6**	78.5**	2.98	0.10	0.17
Small intestinal	3.2	−1.4	2.2	−1.7	1.85	0.44	0.21
Large intestinal	34.1	4.3**	10.3*	10.6*	2.51	0.31	0.52
Total tract	76.9	89.4**	92.1**	87.4*	1.05	0.56	0.32

[1] LRHB, 20% heated rice bran + 40% beet pulp; MRMB, 30% heated rice bran + 30% beet pulp; HRLB, 40% heated rice bran + 20% beet pulp.
[2] Linear (L) and quadratic (Q) effects of rice bran content.
[3] Standard error of the mean.
[4] OM-crude protein-(NDF-NDF bound protein)-fat.
[5] NSC-starch.
*$p < 0.05$; **$p < 0.01$ (different from control diet).

digested with less efficiency (56%). The availability of fatty acids or rice bran is probably restricted in the small intestine.

Intake of DE from the 40% rice bran by-product diet was 13.2 MJ/day less than that for the control diet, although with the other by-product diets it did not differ significantly from the control diet. Because the rice bran level of the by-product diets did not affect the fat digestibility in the whole digestive tract, the lower DE intake for the HRLB diet is attributable to the lower nonstructural carbohydrate intake and lower digestibility of the fiber fractions.

There are two possible causes for decrease of fiber digestibility in the rumen which occurs with increasing rice bran level. One is the different source of dietary NDF; the total NDF in by-product diets consisted of 43% from hay and 57% from the other feedstuffs. Beet pulp has a high level of digestible NDF, which contributes 42%

TABLE 7. NITROGEN (N) INTAKE, PARTITIONING AND DIGESTION IN EACH SEGMENT OF THE DIGESTIVE TRACT OF STEERS FED ON MIXED BY-PRODUCT DIETS

Item	Diet[1]				SEM[3]	Contrasts[2], (P)	
	Control	LRHB	MRMB	HRLB		L	Q
N Intake (g day^{-1})	141.3	136.1	138.4	132.8	1.93	0.39	0.59
Duodenal N flow (g day^{-1})							
Total N	148.5	125.1	129.5	122.2*	4.30	0.95	0.47
Ammonia N	7.6	4.6	5.6	6.0	0.79	0.03	0.14
Nonammonia N	140.9	120.5	123.9	116.2*	3.74	0.64	0.49
Microbial N	78.2	58.6*	53.3*	45.1*	1.32	0.03	0.26
NANMN[4]	62.7	61.9	70.6	71.1	2.46	0.19	0.58
Microbial efficiency							
g N kg^{-1} OMAD[5]	20.7	13.2**	13.8**	14.5**	0.58	0.10	0.87
g N kg^{-1} OMTD[6]	16.1	11.2**	11.3**	11.9**	0.45	0.13	0.37
N degradability in rumen[7]							
% of intake	55.6	54.4	49.0	46.5*	1.41	0.12	0.55
Apparent digestibility							
Small intestinal							
% of duodenal flow	64.0	59.3*	60.2*	52.4*	0.94	0.12	0.15
Large intestinal							
% of ileal flow	31.6	19.0	21.2	22.2	1.87	0.04	0.05
Total tract	74.2	69.8**	71.1*	65.5**	0.39	0.13	0.13

[1] LRHB, 20% heated rice bran + 40% beet pulp; MRMB, 30% heated rice bran + 30% beet pulp; HRLB, 40% heated rice bran + 20% beet pulp.
[2] Linear (L) and quadratic (Q) effects of rice bran content.
[3] Standard error of the mean.
[4] Nonammonia and nonmicrobial nitrogen.
[5] Organic matter apparently digested in the rumen.
[6] Organic matter truly digested in the rumen.
[7] (Total N intake-duodenal NANMN flow)/total N intake.
*$p < 0.05$; **$p < 0.01$ (different from control diet).

and 23% to the total dietary NDF in LRHB and HRLB diets, respectively. The digestibility of NDF derived from the hay and rice bran used in this study was probably much lower than that derived from beet pulp as well as the *in situ* DM disappearance. The second possible reason is the negative association between free fatty acid from rice bran and fiber digestion in the rumen. Devendra and Lewis (1974) speculated about the cause of the negative effect : 1) physical coating of the fiber with fat preventing microbial attack; 2) a modification of the rumen microbial population by toxic effect of fat on some microorganisms; 3) inhibition of microbial activity from surface active effects of fatty acids on cell membranes; 4) reduced cations availability from formation of insoluble complexes with long chain fatty acids.

The amount of rice bran or fat in the diet did not affect starch digestibility in the rumen (table 6). This result is consistent with other studies (McAllan et al., 1983; Zinn, 1989). However, NSP digestibility in the rumen tended to decrease with rice bran level in the by-product diets. Additionally, the control diet also showed a lower digestibility of NSP in the rumen than by-product diets. The main reason for this is that the digestibility of pectin, which is one component of NSP (Van Soest et al., 1991) and plentiful in beet pulp, is high in the rumen (Nocek and Tamminga, 1991). In our previous study (Zhao et al., 1996), the diets containing defatted or heated rice bran showed remarkably low digestibility of NSP in the rumen. Thus, decreasing the beet pulp content in the mixtures of rice bran and beet pulp resulted in reduction in NSP digestibility in the rumen. This suggests that the effect of fat content on the digestion of pectin in the rumen may be small.

The decrease of microbial N flow to the duodenum with rice bran level for the by-product diets reflects the amount of TCHO digested in the rumen. However, the

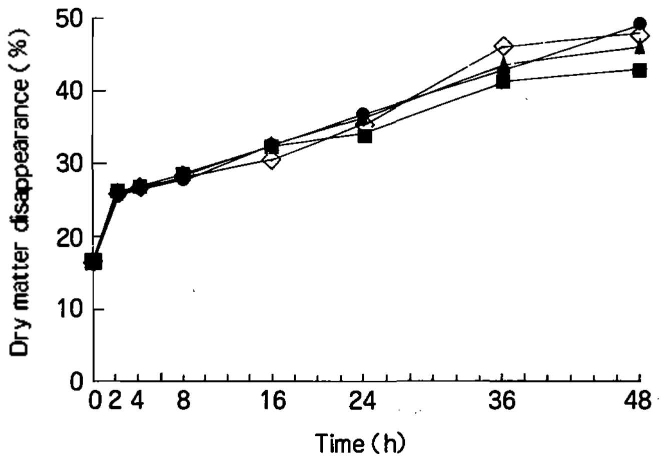

Figure 2. *In situ* (rumen) dry matter disappearance of Italian ryegrass hay from control (■), LRHB (●), MRMB (◇) or HRLB (▲) diet. Standard error of means were 0.47, 0.51, 0.67, 2.45, 1.63, 1.10 and 2.28% for 2, 4, 8, 16, 24, 36 and 48 h of incubation, respectively.

microbial N flow for LRHB, with which contained the greatest amount of digestible TCHO among the all diets, was less than that for the control diet. Maczulak et al. (1981) indicated that *in vitro* growth of major fibrolytic bacteria was inhibited by addition of oleic acid. In rice bran, 42% of total fatty acid was oleic acid (Warren and Farrell, 1990). Therefore, fatty acid from rice bran apparently depressed microbial growth in this study, even though the mixtures of beet pulp and rice bran could provide much available carbohydrate to the microbes as LRHB diet. Such depression of microbial proliferation with the increase of fat intake from rice bran could be the major cause to the reduction of ruminal fiber digestion as mentioned above.

Furthermore, the rice bran used in this study was associated with other problems regarding N utilization; N digestibility in the small intestine decreased with rice bran content. Besides the less amount of microbial N, the heat-processed rice bran used in this study reduced not only the ruminal degradation of dietary N, but also N digestibility in the small intestine. The amount of crude protein digested in the small intestine, namely metabolizable protein, in HRLB diet (the lowest of all the diets at 380 g/day) was slightly below the recommended requirement for the steers used in this study (390 g/day, AFRC, 1993). Thus, the feeding of full fat rice bran to young or high performance cattle may provide insufficient metabolizable protein.

TABLE 8. RUMINAL CHARACTERISTICS OF STEERS FED ON MIXED BY-PRODUCT DIETS

Item	Diet[1]				SEM[3]	Contrasts[2], (P)	
	Control	LRHB	MRMB	HRLB		L	Q
pH	6.0	6.0	6.2	6.2	0.17	0.10	0.54
Ammonia-N (mg dl^{-1})	15.8	14.3	15.0	15.6	0.29	0.22	0.55
Total VFA[4] (mmol dl^{-1})	15.3	16.7**	15.7	13.1	0.55	0.06	0.13
VFA (mol 100^{-1} mol)							
Acetate	59.9	63.2*	60.1	60.0	0.37	0.06	0.53
Propionate	19.2	18.1	20.5	22.8	0.41	0.14	0.37
n-Butyrate	15.4	15.1	14.4	12.4	0.53	0.05	0.01
Isobutyrate	1.5	0.7	0.8	1.5	0.28	0.01	0.03
Valerate	1.3	1.0	1.1	1.4	0.10	0.44	0.67
Isovalerate	2.7	2.0	3.0	1.9	0.15	0.04	0.04

[1] LRHB, 20% heated rice bran + 40% beet pulp; MRMB, 30% heated rice bran + 30% beet pulp; HRLB, 40% heated rice bran + 20% beet pulp.
[2] Linear (L) and quadratic (Q) effects of rice bran content.
[3] Standard error of the mean.
[4] Volatile fatty acids.
*$p < 0.05$; **$p < 0.01$ (different from control diet).

Conclusion

In the mixed beet pulp and full fat rice bran diets, the different ratios of these by-products did not markedly alter the digestion of fat and nonstructural carbohydrate in the whole digestive tract, but it affected the digestion of structural carbohydrate in the rumen. The increase in the level of dietary rice bran decreased fiber digestion and microbial synthesis in the rumen, and reduced DE intake. From the point of view of nutrient digestion, when a high by-product diet containing full-fat rice bran is fed to fattening steers, the rice bran content should be restricted to not more than 30% and be incorporated by readily fermentable by-products such as beet pulp to provide the energy supply.

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