Changes in Histamine Concentration of Ruminal Contents and Plasma in Cattle fed on a Formula Feed and Rolled Barley

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Histamine concentrations of ruminal contents and plasma were determined in the cattle fed on a formula feed and rolled barley. Groups of three Holstein steers were each fed rice straw (0.6 kg) and concentrate rations (10 kg) consisting of 100% rolled barley in diet 1, 50% formula feed and 50% rolled barley in diet 2, 75% formula feed and 25% rolled barley in diet 3, and 100% formula feed in diet 4. Diet 5, a control, consisted of hay, haycube, formula feed (3 kg) and rice straw. Each diet was fed for 4–5 weeks. Ruminal contents and plasma were sampled on the last day of each experimental feeding. The ruminal histamine levels at all sampling were significantly higher in diets 1, 2, 3, and 4 than in diet 5. The levels in diets 3 and 4 were markedly high and increased to the maximum immediately after feeding. The plasma histamine levels were significantly higher in diets 3 and 4 than in diets 1, 2 and 5 at perfeeding. Although there was no characteristic change in the plasma histamine level after feeding diet 1 or 2, the levels remarkably increased in diets 3 and 4. It was evident that ruminal histamine levels of steers fed on diets with higher contents of formula feed increased extremely after feeding. The increased plasma histamine concentration may have reflected the increased ruminal concentration.—*Key words:* Bovine, Histamine, Rumen.

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Laminitis in fattening cattle is a disease caused by overfeeding concentrate. The cause and the mechanism of occurrence of the disease have been discussed from various aspects by a number of workers [6–9, 10, 11, 13, 15, 19]. Takahashi *et al.* [22] reported clinical symptoms of laminitis caused by injection of histamine into the digital artery of cattle. This finding suggests that histamine is one of the important factors of occurrence of laminitis in fattening cattle. It was considered [3, 5, 15] that overfeeding concentrate might increase the population of the ruminal microflora producing histamine from histidine. It was speculated that histamine produced in the rumen might be absorbed from the lower digestive tract and caused laminitis [12]. The changes in the histamine concen-

tration of ruminal contents after overfeeding concentrate were not consistent [4, 15, 17, 18]. There are very few explanations for the different changes in the blood histamine concentrations under the same conditions.

In the present studies, changes in the histamine concentration of the ruminal contents and plasma were examined in cattle fed on diets consisting of a formula feed for fattening and rolled barley at various ratios.

MATERIALS AND METHODS

Three Holstein steers fitted on with ruminal fistulas were used repeatedly. Their mean body weight was 503 ± 32 kg at the start and 567 ± 34 kg at the end of the experiments. They were fed on a formula feed for fattening, rolled barley and a small amount of rice straw [12]. Each of diets 1, 2, 3, 4 and 5 was given for 4 to 5 weeks (Table 1). The ration was given in the equal halves at 9 a.m.

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(first feeding) and 3 p.m. (second feeding). Ruminal contents, blood and urine were sampled immediately before feeding and at 0 (immediately after) 2, 5, 6, 8, 11, 14, 17, 20 and 23 hr after the first feeding and for 24 hr on the last day of each diet period. The blood sample was drawn from the jugular vein into a 10-ml heparinized vacuum tube. The ruminal contents were collected through the rumen fistula by the aid of a stomach tube under suction. The pH value of blood was determined at 37°C with a pH blood gas analyzer (Type 213-227, Instrumentation Laboratory, Italy) and those of ruminal contents and urine with a pH meter (Type H-7, Horiba., Japan). Plasma, ruminal contents and feed were determined for histamine by the procedure of Shore *et al.* [16]. Prior to determination of feed for histidine, fat and carbohydrate were removed [1], and then hydrolyzed with 6 N hydrochloric acid at reduced pressure for 24 hr. The excess acid was removed by vacuum distillation. The histidine content was determined by the method of Spackman *et al.* [20] with a Hitachi amino acid analyser (KLA-3B, Hitachi., Japan).

The F and T tests were used in statistical analysis.

RESULTS

Table one shows the daily intakes of histidine and histamine from each diet. The amount of histidine in the formula feed was the largest of all the feeds tested and in diet 4. The amount of histamine intake was smaller in diet 1 than in diet 5, and larger in diets 2, 3, and 4 than in diet 5. It was also the largest in diet 4.

Table 2 shows changes in ruminal histamine during 24 hr in each diet group. The ruminal histamine levels in diets 1, 2, 3 and 4 were significantly higher ($p < 0.01$) than in diet 5 at all samplings. The ruminal histamine level attained the peak immediately after the first and second feedings of diets 3 and 4. Significant differences ($p < 0.05$ or 0.01) were observed from immediately after feeding till 11 hr between diet 4 and the other groups. The ruminal histamine level increased slightly in diets 1 and 2 immediately after the first feeding but no more increase was found after the second feeding. In diet 5,

Table 1. Daily intakes of feed, histidine and histamine by cattle fed on each diet

Experimental Diet		Feed intake (kg)	Histidine intake (g)	Histamine intake (mg)
1	Barley ^{a)}	10	19	28
	Rice straw	0.6		
2	Formula feed	5.0	28	184
	Barley	5.0		
	Rice straw	0.6		
3	Formula feed	7.5	33	262
	Barley	2.5		
	Rice straw	0.6		
4	Formula feed	10.0	37	340
	Rice straw	0.6		
5	Hay	6.0	25	126
	Haycube	0.8		
	Formula feed	3.0		
	Rice straw	3.0		

a) Rolled barley

Table 2. Histamine concentrations of ruminal contents in cattle fed on each diet

Hr pre- and post-feeding	Diet 1		Diet 2		Diet 3		Diet 4		Diet 5	
	X	SD	X	SD	X $\mu\text{g/ml}$	SD	X	SD	X	SD
Pre-feeding	3.0 ^{a)}	0.6	3.7 ^{a)}	2.9	2.7 ^{a)}	0.9	1.7 ^{a)}	0.8	0.2 ^{b)}	0.0
First feeding										
0	4.3 ^{a)}	1.8	4.1 ^{a)}	1.7	7.8 ^{c)}	2.2	6.3 ^{c)} **	1.4	0.2 ^{b)}	0.1
2	1.8 ^{a)}	1.3	1.7 ^{a)}	0.6	2.2 ^{a)}	0.8	3.8 ^{c)} **	0.5	0.1 ^{b)}	0.0
5	2.0 ^{a)}	1.1	1.9 ^{a)}	0.9	1.0 ^{a)}	0.1	3.9 ^{c)} **	0.7	0.1 ^{b)}	0.1
Second feeding										
6	1.4 ^{a)}	0.5	1.9 ^{a)}	0.7	4.2 ^{c)} *	0.7	6.3 ^{c)} **	1.4	0.2 ^{b)}	0.1
8	1.0 ^{a)}	0.8	2.0 ^{a)}	0.7	2.8 ^{a)}	0.7	5.9 ^{c)} *	1.5	0.2 ^{b)}	0.1
11	1.4 ^{a)}	0.4	1.8 ^{a)}	0.2	1.7 ^{a)}	0.1	7.0 ^{c)} *	3.9	0.2 ^{b)}	0.0
14	1.6 ^{a)}	0.8	1.6 ^{a)}	0.3	1.4 ^{a)}	0.4	4.5 ^{a)}	2.8	0.1 ^{b)}	0.0
17	2.2 ^{a)}	0.5	1.8 ^{a)}	0.3	1.8 ^{a)}	0.1	4.0 ^{a)}	2.7	0.1 ^{b)}	0.0
20	2.1 ^{a)}	0.8	2.1 ^{a)}	0.5	1.6 ^{a)}	0.1	3.4 ^{a)}	2.7	0.1 ^{b)}	0.0
23	2.3 ^{a)}	0.8	2.5 ^{a)}	0.8	1.9 ^{a)}	0.2	2.4 ^{a)}	1.9	0.1 ^{b)}	0.0

Figures are mean (X) $\pm$ standard deviation (SD).

a, b, c) There are significant differences between a and c ($P < 0.05$) and between a and b, and b and c ($P < 0.01$).

*, ** Significantly different from pre-feeding value of the same column (*; $P < 0.05$, **; $P < 0.01$).

Table 3. Histamine concentrations of plasma in cattle fed on each diet

Hr pre- and post-feeding	Diet 1		Diet 2		Diet 3		Diet 4		Diet 5	
	X	SD	X	SD	X ng/ml	SD	X	SD	X	SD
Pre-feeding	40 ^{a)}	11	27 ^{a)}	6	61 ^{b)}	7	91 ^{c)}	11	23 ^{a)}	22
First feeding										
0	28 ^{a)}	13	20 ^{a)}	2	78 ^{b)}	13	366 ^{c)} **	44	18 ^{a)}	18
2	42 ^{a)}	25	25 ^{a)}	9	150 ^{b)} **	38	659 ^{c)} **	140	17 ^{a)}	14
5	60 ^{a)}	34	34 ^{a)}	4	91 ^{b)} **	18	69 ^{b)} *	9	15 ^{d)}	12
Second feeding										
6	42 ^{a)}	46	46 ^{a)}	16	77 ^{b)}	7	70 ^{b)}	11	20 ^{d)}	17
8	54 ^{a)}	15	35 ^{a)}	10	89 ^{b)}	18	64 ^{b)}	8	17 ^{d)}	12
11	42 ^{a)}	9	48 ^{a)}	20	52 ^{a)}	16	69 ^{d)} *	5	18 ^{a)}	17
14	41 ^{a)}	6	58 ^{a)}	29	30 ^{a)} **	15	74 ^{b)}	9	31 ^{a)}	30
17	35 ^{a)}	1	47 ^{a)}	13	76 ^{b)}	4	84 ^{b)}	9	30 ^{a)}	25
20	39 ^{a)}	11	39 ^{a)}	9	67 ^{b)}	17	69 ^{b)} *	4	27 ^{a)}	29
23	43 ^{a)}	11	40 ^{a)}	8	72 ^{b)}	4	109 ^{c)}	5	29 ^{a)}	27

Figures are mean (X) $\pm$ standard deviation (SD).

a, b, c, d) There are significant differences between a and d ($P < 0.05$), and between a and b, a and c, and b and c ($P < 0.01$).

*, ** The values are significantly different from pre-feeding one in the same column (*; $P < 0.05$, **; $P < 0.01$).

Fig. 1. PH values of ruminal contents, blood and urine of cattle over fed on concentrate
 Each dot and vertical bar represent the mean $\pm$ standard deviation of three steers and dot only the mean of two steers.
 -: Feeding time

ruminal histamine concentration was about 10% less than that in the other diet groups, and there was no increase after feeding.

Table 3 shows the plasma histamine levels for 23 hr. The levels were higher in diets 3 and 4 than in diet 5 throughout the sampling period, and higher until 2 hr after the first feeding in diet 4 than in diets 1, 2 and 3. Thereafter, they were higher in diets 3 and 4 than in diets 1 and 2. The level increased remarkably in diet 4 after the feeding and the highest ($659 \pm 140 \text{ ng/ml}$) in 2 hr after the first feeding. It also increased to a peak in 2 hr after the first feeding in diet 3. The levels were slightly higher in diets 1 and 2 than in diet 5, but there was no increase after the feeding.

Fig. 1 shows the pH values of ruminal contents, blood and urine for 23 hr. Ruminal pH showed a tendency to decrease after feeding, not reaching below 6 in diet 5, but 4.8 in

8 hr after the first feeding in diets 3 and 4. The pH values in 23 hr returned to the pre-feeding levels in these diets groups. The pH values of blood and urine decreased gradually after the feeding and were lower in diets 1, 2, 3, and 4 than in diet 5. Urine pH values were particularly low in diets 1 and 2.

DISCUSSION

The ruminal and blood histamine levels of steers fed on 10 kg of concentrate consisting of formula feed and rolled barley at various ratios were determined periodically. The experimental steers were fairly heavy as compared with those used in the previous studies [12]. The weight gain was only 60 kg on the average during the experimental period. Therefore, we made no attempt to increase the quantity of feed.

Irwin *et al.* [4] suggested that the ruminal histamine concentration might increase by

decarboxylation of histidine by ruminal bacteria. It may depend upon feed ingredient and histamine concentration of diet [15, 23]. In the present studies, the levels were higher in the groups fed on diet rich in concentrate (diets 1–4) than in diet 5 and remarkably increased after the feeding, especially in diets 3 and 4. The increase might have resulted mainly from decarboxylation of histidine contained by the feeds by the action of ruminal microorganisms. It is also assumed that the ruminal histamine concentration depends upon the histamine and histidine contents of feed.

Irwin *et al.* [4], Koers *et al.* [5] and Sanford [15] stated that ruminal histamine markedly elevated when the ruminal pH decreased from 6.8 to 4.7 in experimental acidosis. In the present studies, the pH values of rumen, blood and urine were lower in the groups overfed with concentrate than in diet 5. The ruminal pH decreased to 5 or lower. Since the low ruminal pH enhances histidine decarboxylation by the ruminal microorganisms [4], the increased ruminal histamine in diets 1–4 may have resulted from the decreased ruminal pH. The precipitous fall of ruminal pH may have been due to lactic acid and volatile fatty acid produced in the rumen after feeding [14].

Suber *et al.* [21] noted no statistical significance in the blood histamine value between forage-fed and concentrate-fed steers, and a low correlation between ruminal and blood histamine responses in steers suffering from laminitis due to carbohydrate-induced acidosis. In the present studies, the blood histamine level was higher after the first feeding in diets 3 and 4, in contrast to the previous results [21]. The discrepancy may have resulted from the difference in concentrate, formation of histamine in the rumen [15, 17, 18, 23] and histamine metabolism in the rumen and blood [2]. It is suggested that the increased blood histamine concentration may reflect the increased ruminal histamine con-

centration by feeding a large amount of formula feed for fattening cattle. Maclean [7] and Takahashi *et al.* [22] pointed out the possible relationship between laminitis and barley. From the present results, it is considered that the formula feed may also implicate in occurrence of laminitis if histamine is one of the causes of the disease in fattening cattle.

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要 約

濃厚飼料多給牛の採食に伴う第一胃内容物および血漿ヒスタミンの変動: 元井霞子・小原嘉昭¹⁾・新林恒一 (農林水産省家畜衛生試験場, ¹⁾北海道支場)——肥育用配合飼料および圧べん大麦多給時における牛の第一胃内容物および血漿中のヒスタミンの採食に伴う変動について観察した。第一胃カニューレを装着した実験牛3頭を圧べん大麦のみ100%給与区 (飼料区1), 牛肥育用の配合飼料50%と大麦50% (飼料区2), 配合飼料75%と大麦25% (飼料区3), ついで配合飼料のみ100% (飼料区4) で各4~5週間順次飼育し, さらに4~5週間, 乾草, ヘイキューブ, 稲わらと配合飼料 (飼料区5) で飼育した。血液, 第一胃液および尿の採材は各飼料区の最終日に行った。第一胃内のヒスタミン濃度はすべての濃厚飼料給与区 (飼料区1~4) において飼料区5より高い値を示した。とくに飼料区3と4では著明に高く, 採食後その濃度は最高値に達した。血漿ヒスタミン濃度は飼料区3と4で採食前に飼料区1, 2と5よりも明らかに高い値を示した。飼料区1と2では採食後, 特異的な変化を示さなかったが, 飼料区3と4では採食後著明に増加した。以上の結果から, 配合飼料を多給した場合は第一胃内容物のヒスタミン濃度は採食後著しく増加し, この増加が血中濃度に反映するものと思われた。