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Effect of Feeding Frequency on Digestibility, Property of Rumen Liquor and Blood under the Condition of Different Ratios of Concentrate and Roughage in Sheep

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Summary

Four sheep fitted with rumen fistula were used for this experiment. Experimental animals were fed with concentrate (commercial formula feed for beef cattle) and Italian ryegrass hay chopped at the length of 2 cm, by mixing with proper water ; i. e., the ratios of concentrate and roughage were set 8 : 2 (high concentrate ration) and 2 : 8 (high roughage ration). The amounts of ration were determined at 80% level in case of *ad lib.* feeding at both ratios. Two feeding frequencies were set, according to once feeding and three times feeding at every eight hours per day. Digestion trial was conducted with 4×4 Latin square method from four treatments of different concentrate and roughage ratio with feeding frequency. On the next day of each trial, rumen liquor and blood were sampled during 24 hours. Digestibility tended to be higher in three times feeding than that of once feeding with high concentrate ration. In case of high roughage feeding, however, digestibility tended to be lower in three times feeding than in once feeding. Especially, digestibility of nitrogen free extract and organic cell wall was remarkably lower in three times feeding than once feeding ($P < 0.05$). Total volatile fatty acid (VFA) content increased immediately after feeding and gradually decreased during 24 hours in once feeding of both ratios of concentrate and roughage. In three times feeding of both ratios, on the other hand, VFA content showed three peaks after each feeding.

Key words : concentrate and roughage, digestibility, feeding frequency, rumen liquor, sheep

Introduction

In ruminant animals, it is well known that the difference of ratios of concentrate and roughage rations has a great influence upon the productivity of fattening and milk secretion. As for example, the higher roughage ration was provided, the more milk fat was contained in dairy cow[3,13,19,27], and in beef cattle, the higher concentrate ratio was for the latter term, the better feed efficiency and property of dressed carcass were observed[14]. The reason was due to the different ratio of acetic acid to propionic acid fermentation from carbohydrate in rumen with different ratio of concentrate and roughage; i. e., the high ratio that milk fat was synthesized from acetic acid was precursor in mammary gland[19,27] and the low ratio that body weight gain and adipose tissue synthesis were accelerated[22,24] by insulin secretion stimulated due to propionic acid[23,25,26] produced from fermentative carbohydrate in rumen. In the relationship between concentrate-roughage ratio and digestibility, high concentrate ration decrease the digestibility of fibrous constituent because the activity of microorganism weakened owing to rapid decrease with accumulation of lactic acid fermentation from water soluble carbohydrate in rumen liquor[8,10,18].

It is thought that feeding frequency influence the productivity of livestock. Morita and Nishino[12] reported about the effect of eating behavior of grass hay in steer. In dairy cow, much milk fat content was observed with increased feeding frequency and low insulin secretion

of blood plasma after feeding[20]. Growing sheep gave greater body weight-gain and higher feed efficiency when offered daily ration in eight feeds than when given the same quantity in one feed[4]. In digestibility of diet, feeding frequency had no effect on the digestibility in growing pig[21]. In ruminant animals, however, several data were reported but the same result has not been obtained yet.

This experiment was carried out to examine the effect of feeding frequency with different ratios of concentrate and roughage on digestibility, property of rumen and blood on sheep.

Materials and Methods

Four Suffolk castrated sheep (average body weight 48.3 kg) with rumen fistula were used for this experiment. Experimental animals were fed with concentrate (commercial formula feed for beef cattle) and Italian ryegrass hay chopped at the length of 2 cm, by mixing with 50% water of the total amount of ration. Two ratios of concentrate and roughage were set at 8 : 2 (high concentrate ration) and 2 : 8 (high roughage ration). The amounts (g/BW (kg) $^{0.75}$) of ration were determined at 80% level in case of *ad lib.* feeding in both ratios ; i. e., 67.2 in high concentrate ration and 55.3 in high roughage ration, respectively. Two feeding frequencies were set, according to once feeding per day and three times feeding at every eight hours per day. In three times feeding, one-third of total ration was divided and fed equally. Digestion trial was conducted by total collection of feces for five consecutive days after seven preliminary days. The experiment was designed with 4×4 Latin square method. On the next day of each trial, rumen ingesta and blood were sampled at 0, 1, 3, 6, 12 and 18 hours after feeding in case of once feeding and 0, 1 and 4 hours after feeding in case of three times feeding, respectively. Blood samples were drawn from the catheter into 20 ml evacuated heparinized tubes. Blood plasma and rumen liquor filtered through double-folded cheese cloth were stored at −20℃ until analysis.

The chemical composition of ration and feces were analyzed by the conventional method[11]. Organic cellular content and (OCC) and organic cell wall (OCW) were determined by the method of mixed enzyme system using amylase and protease[7]. Volatile fatty acid (VFA) was steam-distilled and measured by the gaschromatography (Hitachi G-5000A) using a glass column (2m × 3mm) packed with Unisole F-200 (30/60 mesh). The pH of rumen liquor was determined by a pH meter (Hitachi Horiba M-7). Ammonium-N of rumen liquor was estimated by microdiffusion method of Conway[2]. Hematocrit value of blood was determined by centrifugation at 12,000 rpm for 5 min. Plasma insulin was assayed by a radioimmunoassay kit (Eiken Chemical Co., Ltd.).

All analytical values at 24 hours were indicated with the values at 0 hour. The significances of difference were evaluated by analysis of Duncan's multiple range test in SAS[16].

Results and Discussion

The chemical compositions of rations used in this experiment are presented in Table 1. The digestibility and digestible nutrients are presented in Table 2. Concentrate contained higher crude protein and OCC, lower crude fiber and OCW which were indigestible fibrous constituents than roughage. Digestibilities of all constituents tended to be higher in three times feeding than

Table 1. Chemical composition of rations used in the experiment

Ration	Moisture (%)	C. protein (%)	C. fat (%)	NFE[1] (%)	C. fiber (%)	C. ash (%)	OCC[2] (%)	OCW[3] (%)
Concentrate[4]	13.8	11.5	4.8	58.8	4.5	6.6	60.5	19.1
Roughage[5]	13.3	4.3	1.6	46.0	30.1	4.7	21.0	61.0

1) ; Nitrogen free extract. 2) ; Organic cellular content. 3) ; Organic cell wall. 4) ; Concentrate was used formula feed "Dyna-Beef" made by Nihon Nosan Kogyo Co., LTD. 5) ; Roughage was used Italian ryegrass hay chopped at length of 2 cm.

Table 2. Digestibility and digestible nutrients in once and three times feedings with different ratios of concentrate and roughage

Item	High concentrate ration[1]		High roughage ration[1]	
	Once feeding	Three times feeding	Once feeding	Three times feeding
Digestibility (%)				
Crude protein	69.7±1.2[2]	74.4±4.3	39.6±15.5	32.3±0.0
Crude fat	72.9±9.2	82.3±9.2	56.3±11.9	53.1±8.4
NFE[4]	84.1±1.1	85.4±2.4	74.5±4.2[a3]	60.2±0.4[b]
Crude fiber	32.5±6.4	42.6±8.9	38.8±6.8	25.5±4.4
OCC[5]	90.5±0.7	91.6±1.5	84.4±3.8	78.3±3.3
OCW[6]	35.3±4.9	44.0±9.3	36.9±3.2[a]	21.1±5.2[b]
Digestible nutrients (%)				
DCP[7]	7.1±0.1	7.5±4.3	2.3±0.9	1.9±0.0
TDN[8]	65.0±1.8	68.3±3.5	52.9±2.5[a]	41.0±0.7[b]

1); Experimental animals were fed the ration which was equivalent to 80 % of the amount at *ad lib.* feeding; i. e., 67.2g/BW (kg)$^{0.75}$/day in high concentrate ration and 55.3g/BW (kg)$^{0.75}$/day in high roughage ration, respectively. The weight ratios were 8 : 2 (high concentrate ration) and 2 : 8 (high roughage ration) of concentrate and roughage, respectively. 2); Mean ± standard deviation. 3); Means with different superscripts are significantly different at the 0.05 probability level. 4); Nitrogen free extract. 5); Organic cellular content. 6); Organic cell content. 7); Digestible crude protein. 8); Total digestible nutrients.

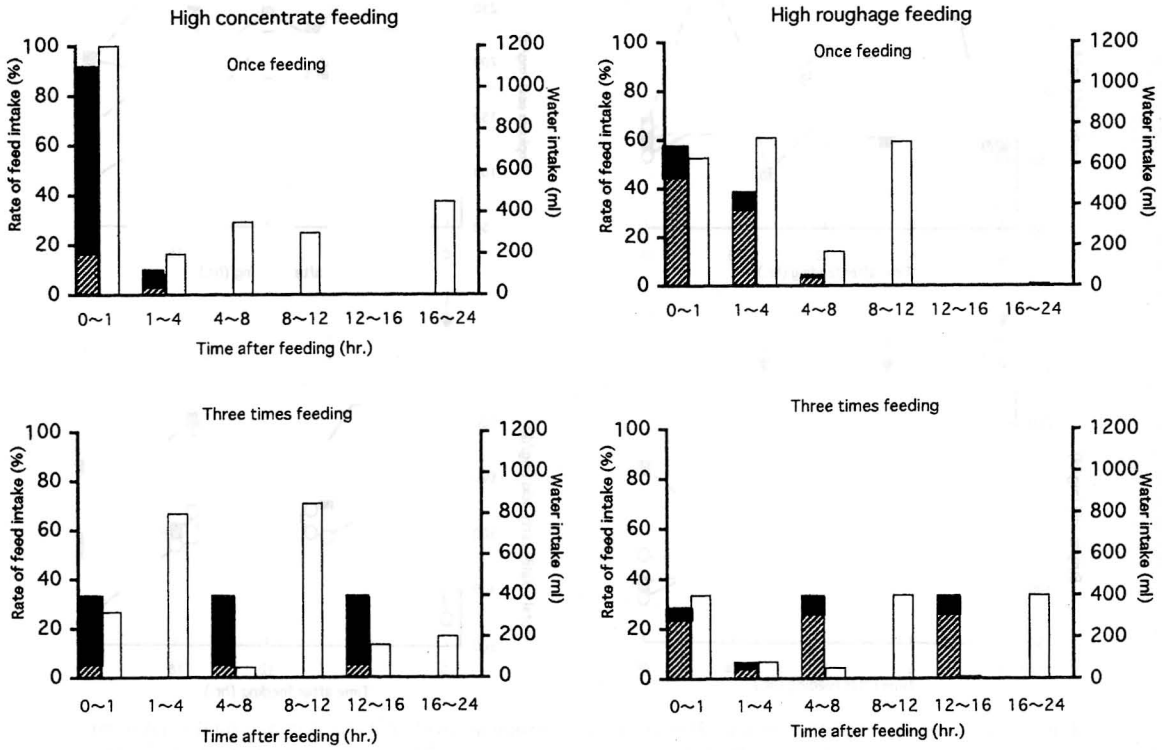

Fig. 1. Changes in feed intake with different feeding frequencies. The left bar gragh indicates percentage of total ration fed to experimental animals. The right bar graph indicates amount of water intake. ■; concentrate. ▨; roughage. □; water.

once feeding in case of high concentrate ration but there was no significant difference between once and three times feedings ($P \geqq 0.05$). In high roughage ration, however, digestibilities tended to be lower in three times feeding than in once feeding. Especially, digestibility of carbohydrate of nitrogen free extract (NFE) and OCW was remarkably lower in three times feeding than in once feeding ($P < 0.05$). Consequently, in total digestible nutrients (TDN) of high roughage ration, the decrease of three times feeding was 11.9% as compared to once feeding.

Changes in feed and water intake during 24 hours are shown in Fig. 1. In once and three times feedings of high concentrate ration, almost amount of ration was fed within one hour after feeding. In high roughage ration, feed intake continued till eight hours in three times feeding as compared with ending within one hour in once feeding. Much water intake was observed in one hour after feeding at once feeding in high concentrate ration ; i. e., approximately 1,200 ml per head. Total water intake of once feeding (2,540 ml) in high concentrate ration was almost the same as in three times feeding (2,480 ml). In high roughage feeding, however, water intake of three times feeding (1,310 ml) was 58% of once feeding (2,240 ml).

Changes in VFA concentration are shown in Fig. 2 as mg/dl, and in Fig. 3 as mol% and ratio of propionic acid to acetic acid, respectively. Concentration (mg/dl) of propionic acid and total VFA changed at more level in high concentrate ration than in high roughage ration, but the differences of acetic acid and butyric acid were not clear between both ratios of rations. Consequently, high

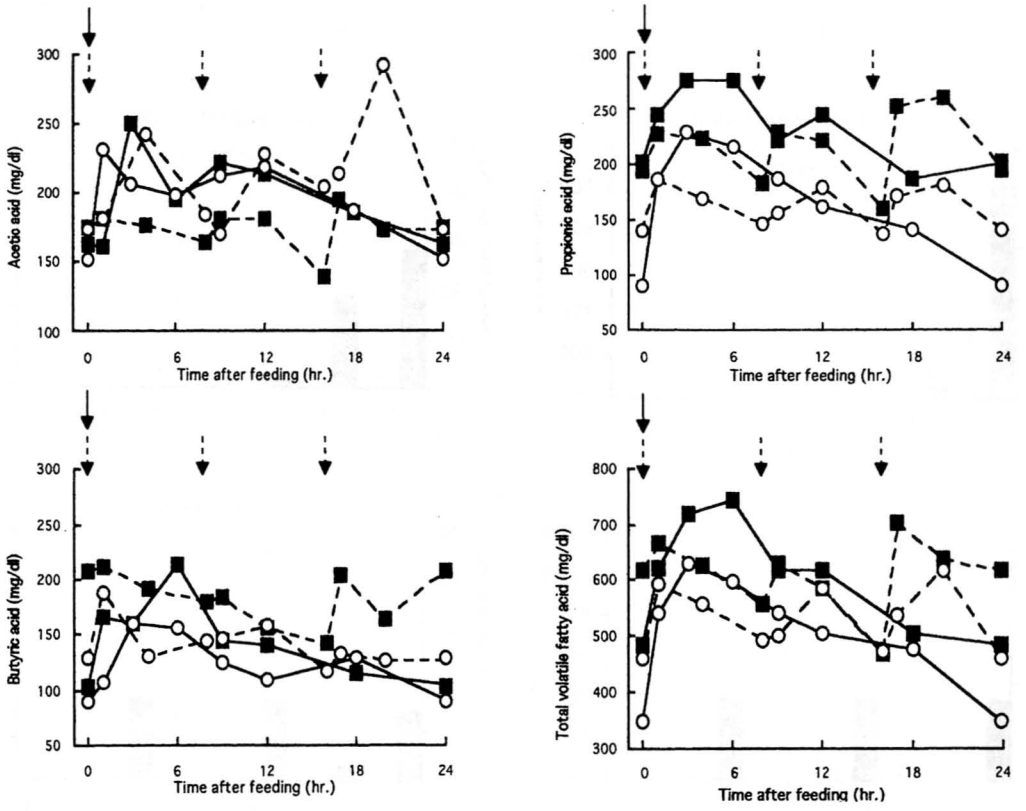

Fig. 2. Changes in concentration (mg/dl) of acetic acid, propionic acid, butyric acid and total volatile fatty acid in rumen liquor with different feeding frequencies. The arrows indicate feeding. ↓ ; once feeding. ⇣ ; three times feeding. ■—■ ; once feeding with high concentrate feeding. ■---■ ; three times feeding with high concentrate feeding. ○—○ ; once feeding with high roughage feeding. ○---○ ; three times feeding with high roughage feeding.

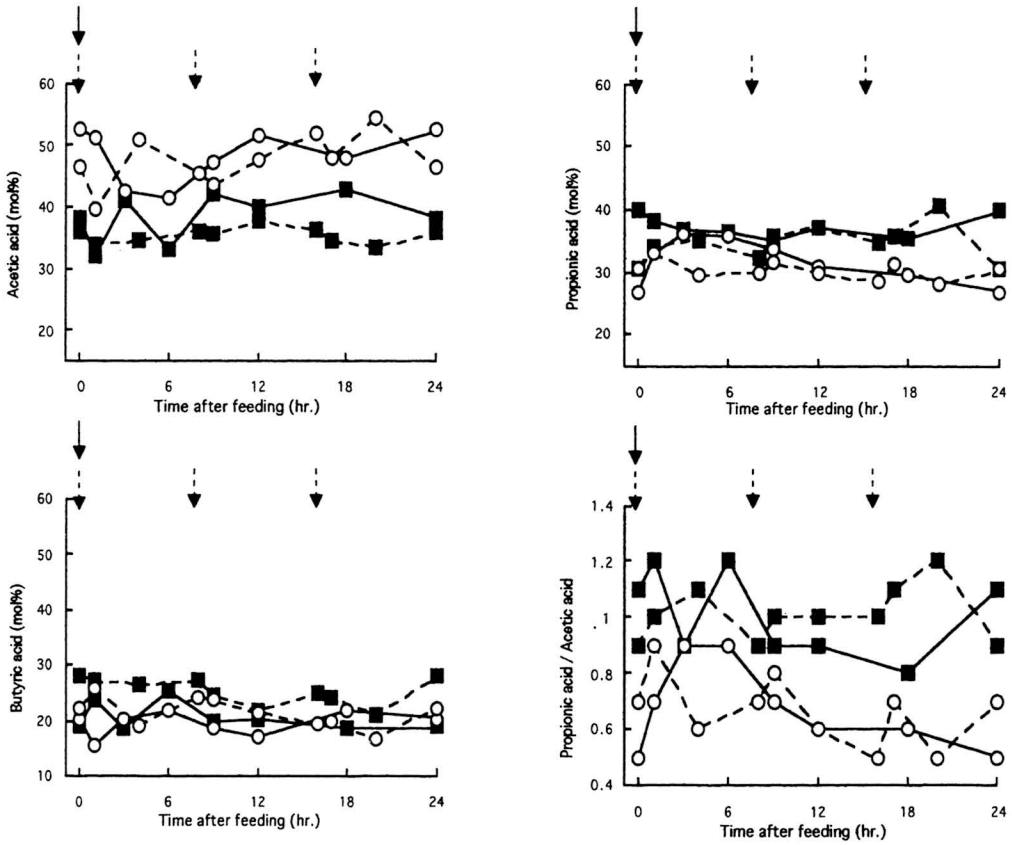

Fig. 3. Changes in concentration (mol%) of acetic acid, propionic acid, butyric acid and ratio of propionic acid to acetic acid in rumen liquor with different feeding frequencies. The arrows indicate feeding ↓ ; once feeding. ↓ ; three times feeding. ■—■ ; once feeding with high concentrate feeding. ■···■ ; three times feeding with high concentrate feeding. ○—○ ; once feeding with high roughage feeding. ○···○ ; three times feeding with high roughage feeding.

concentrate ration indicated higher molar % of propionic acid and ratio of propionic acid to acetic acid than high roughage ration. In once feeding of both ratios of rations, concentrations of total VFA and the ratio of propionic acid to acetic acid increased immediately after feeding and gradually decreased during 24 hours. In three times feeding of both ratios, on the other hand, three peaks were observed after each feeding. Changes in pH and ammonium-N of rumen liquor, hematocrit and insulin concentration of blood plasma are shown in Fig. 4. High concentrate ration changed at lower pH and higher hematocrit and insulin levels than high roughage ration, respectively. Hematocrit value immediately increased after feeding in both rations but there was no obvious difference among four treatments.

McGuire *et al.*[9] reported that in steers offered complete pelleted ration contained 32% corn cob, increasing the frequency of feeding from one to six times daily significantly decreased crude protein digestibility, because ingesta might move out of the rumen before extensive breakdown of dietary protein or synthesis of bacterial protein could occur. Moreover, Rakes *et al.*[15] reported a significant decrease in digestibility of other nutrients, except ether extract, with an increase in feeding frequency. Digestibility of crude protein decreased with increased feeding frequency, but digestibilities of dry matter, organic matter and cell wall content constituents were not affected by feeding frequency[1]. Gorton and Tribe[4] speculated that the more feeding frequency was, the faster passage speed out of reticulo-rumen. It was

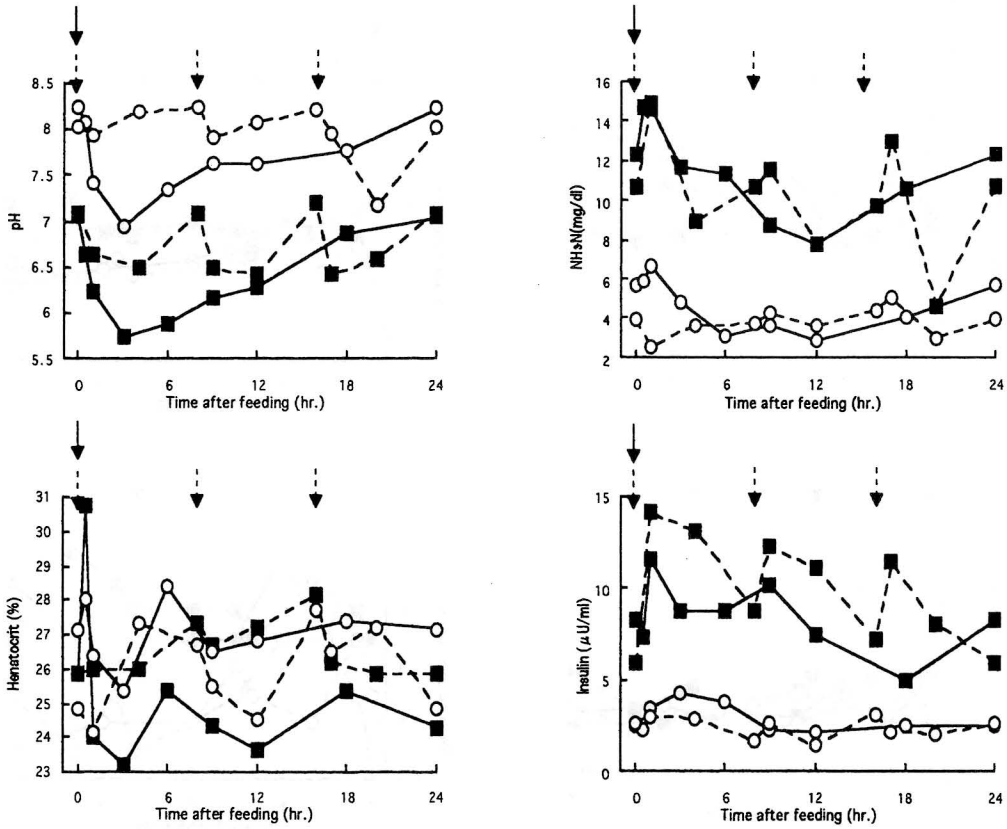

Fig. 4. Changes in pH and NH_3–N concentration of rumen liquor, hematocrit and insulin concentration of blood plasma with different feeding frequencies. The arrows indicate feeding. ↓ ; once feeding. ↓ ; three times feeding. ■—■ ; once feeding with high concentrate feeding. ■---■ ; three times feeding with high concentrate feeding. ○—○ ; once feeding with high roughage feeding. ○---○ ; three times feeding with high roughage feeding.

thought that in this experiment of high roughage feeding, the digestibilities of carbohydrate of NFE and OCW might be lower in three times feeding than once feeding owing to OCW, main part of carbohydrate escaped from fermentation by microorganism because of rapid passage out of rumen. In case of three times feeding of high roughage ration, therefore, the pH slightly decreased as compared remarkable decrease in once feeding after feeding and water intake was small amount due to low VFA production. The reason why no significant difference was observed between once and three times feeding in high concentrate ration might be that the fermentative constituents of the diet were digested in the lower part of digestive tract or the fermentation of carbohydrate (mainly OCW) proceeded favorably due to comparatively high pH value after feeding, although the ingesta rapidly passed out of rumen in three times feeding.

Propionic acid molar % and the ratio of propionic acid to acetic acid were high with decreasing feeding frequnency[5,6,19,20] and promoted insulin secretion[20]. Sutton *et al.*[19] observed that milk fat content was lower in twice feeding than six times feeding, especially, this phenomenon was clearly shown in high concentrate ration. Sato *et al.*[17] reported that diurnal fluctuations of ruminal pH were lessened with increasing feeding frequency and a decline of acetate/propionate ratio and the elevation of ruminal NH_3 level were more remarkable in twice feeding than four times feeding. In high concentrate ration of this experiment, the decreasing width of ruminal pH after feeding was larger in once feeding than

in three times feeding as was reported by of Sato *et al.*[17] Experimental animals, however, was not infected with a disease of acidosis.

It is necessary that the turnover rate of ingesta in rumen and long term experiment should be carried out to clarify the difference of productivity with different feeding frequencies in high concentrate and roughage rations.

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メン羊における濃厚飼料と粗飼料の異なる給与比下での給与回数が消化率並びに第一胃内液と血液性状に及ぼす影響

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摘　　要

第一胃フィステルを装着したメン羊4頭を供試動物とした．濃厚飼料（肉牛用市販配合飼料）と2cmに切断したイタリアンライグラス牧乾草の給与比を8：2（濃厚飼料多給）と2：8（粗飼料多給）を設定し，飼料の給与量はそれぞれの給与比で不断給与したときの80%とした．給与回数を1日1回（24時間毎給与）と1日3回（8時間毎給与）の4処理を設定し，4×4のラテン方格法により消化試験を実施した．各試験終了の翌日に第一胃内液と血液を24時間に亘り採取した．成分消化率は，濃厚飼料多給のとき1回給与より3回給与が高くなる傾向を示した．しかし，粗飼料多給のときは，1回給与より3回給与が低くなる傾向を示し，特に，可溶無窒素物と細胞壁物質の消化率が著しく低下した（$P<0.05$）．その結果，粗飼料多給の可消化養分総量では，3回給与は1回給与より11.9%低くなった．粗飼料多給の場合，給与回数を多くすることは栄養価の改善につながらないことを示唆した．第一胃内液の揮発性脂肪酸，pH，NH_3－Nと血液ヘマトクリット及び血漿中インシュリンは，いずれの給与比とも1回給与で飼料給与後一過性の上昇或いは下降を示したが，3回給与ではそれぞれの給与に伴うピークの出現がみられた．

キーワード：濃厚飼料と粗飼料，消化率，給与回数，第一胃内液，メン羊