Digestion and Balance Trials of Goats Fed the Liquid Diet Composed of 1,2-Propanediol, Molasses, Urea, Vitamins and Minerals with Roughage

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Abstract Digestion trial and nitrogen and mineral balance experiments were carried out to determine the nutritive values of the liquid diets containing 1,2-propanediol, molasses, urea and vitamin-mineral mixture with hay or rice hull using Japanese meat-type goats. The liquid diet in Experiment 1 (Diet 1) contained 50.8% molasses and 25.4% 1,2-propanediol as energy sources and 3.8% urea as nitrogen source. The liquid diet in Experiment 2 (Diet 2) contained 57.4% molasses, 28.7% 1,2-propanediol and 4.4% urea. No toxic effect of urea was observed. Apparent digestibilities of crude protein and organic matter were 77.1 and 79.7% for Diet 1 and 68.4 and 65.4% for the mixed ration of Diet 2 and rice hull, respectively. Nitrogen retention was 1.11 g/day for the mixed ration of Diet 1 and hay and -0.93 g/day for the mixed ration of Diet 2 and rice hull. Balance of Ca and P were positive in the mixed ration of Diet 1 and hay, but negative in Experiment 2. Mg balance was negative throughout the experiments. The combination of the liquid diet and hay may be beneficial for the utilization of hay and the dietary inclusion of 1,2-propanediol may not be suppressive for the urea utilization.

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1,2-propanediol can be used as an energy source for the ruminant, since the compound is a glucogenic substance mainly to be absorbed from the ruminal wall and partly to be converted to propionic acid in the rumen¹⁻⁴⁾. In our previous work³⁾, weight gain of young goats fed a concentrate containing 9% 1,2-propanediol is significantly higher than that fed a concentrate containing 9% starch. In the present work 1,2-propanediol was used as an energy source of the liquid diet in which most of the protein source was furnished by urea. Molasses was added to this diet, since the combination of molasses and urea is known to be beneficial for the urea utilization⁵⁾. However, no information has been available concerning the effect of the combination of 1,2-propanediol and molasses-urea diet. So, digestion and metabolism experiments were carried out using goats fed the liquid diet and roughage. As minerals and vitamins were also supplemented to this diet to satisfy the requirements, mineral balance experiments were also done to investigate the utilization of supplementary major minerals in the liquid diet.

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Materials and Methods

Experimental animal

Three castrated, Japanese native meat-type goats of 10 months of age weighing about 15 kg were used in Experiment 1. Experiment 2 was carried out using the same individuals used in Experiment 1. They were 18 months old and the average body weight was 20 kg in Experiment 2.

Experimental diets

Table 1 shows the ingredients and chemical compositions of the liquid diets. The chemical compositions of hay used in Experiment 1 and rice hull used in Experiment

Table 1. Ingredients of liquid diets and chemical composition of liquid diets and roughages.

	Diet 1	Diet 2	Hay	Rice hull
Ingredients composition	 (%)			
1,2-propanediol	25.4	28.7		
Molasses, cane	50.8	57.4		
Lecithin, soybean	—	1.2		
Urea	3.8	4.4		
CaCl ₂ ·2H ₂ O	1.6	1.8		
NaCl	1.4	1.6		
NaH ₂ PO ₄ ·2H ₂ O	2.5	2.9		
MgCl ₂ ·6H ₂ O	1.5	1.7		
Vitamin mixture ¹⁾	0.2	0.2		
Trace mineral mixture ²⁾	0.1	0.1		
Water	12.7	—		
Chemical composition				
Dry matter	76.4	84.7	88.1	89.8
..... (% of DM)	 (% of DM)			
Crude protein	16.9	16.9	9.3	3.0
Ether extract	0.0	1.2	2.4	0.3
Nitrogen free extract	72.0	69.2	48.8	34.0
Crude fiber	0.0	0.0	28.0	44.5
Crude ash	11.1	12.8	11.5	18.2
Ca	1.07	1.20	0.44	0.07
P	0.68	0.72	0.30	0.02
Mg	0.38	0.33	0.27	0.01
Na	1.48	0.91	0.09	0.04
K	2.09	2.88	2.42	0.23
..... (cal/g DM)	 (cal/g DM)			
Gross energy	3760	3650	4100	3800

1) Vitamin mixture (1g) contained; vitamin A palmitate, 2500 I.U.; ergocalciferol, 250 I.U.; thiamine mononitrate, 1mg; riboflavin, 1.5 mg; nicotinamide, 10 mg; pyridoxine, 1.5 mg; folic acid 0.15 mg; calcium pantothenate, 5 mg; cyanocobalamin, 1 µg; ascorbic acid, 37.5 mg; dl-α tocopherol, 1 mg; biotin, 20 µg. 2) Micro mineral mixture (1g) contained; Mn, 100 mg; Fe, 100 mg; Cu, 20 mg; Zn, 120 mg; I, 2.0 mg.

2 are also shown in Table 1. The rice hull treated with heat (160°C) and pressure was purchased from Tsurumi-Soda Co., Yokohama, and the hard texture is softened.

Experimental procedure

Digestibility, nitrogen balance and mineral balance data were obtained by total collection method. In Experiment 1, restricted amounts of a well-mixed ration of Diet 1 and hay (200 g of Diet 1 and 300 g of hay daily) were fed in the first period and hay only was fed in the second period. The digestibility of Diet 1 was calculated by the difference of the two digestibilities. In Experiment 2, a mixed ration consisting of 75% of Diet 2 and 25% of rice hull was fed *ad libitum*. In each Experiment, water was given freely. Adaptation period to the rations was 4 weeks and sample collection period was 7 days. The animals were kept in metal cages.

Analytical methods

Fecal samples were dried at about 60°C for 24 hr and equilibrated with atmospheric moisture and a subsample was taken for the chemical analysis. Chemical composition of diets, feces and urine were determined by the conventional method. Gross energy of diets and feces were determined with an adiabatic bomb calorimeter. Ca, Mg, Na and K were determined by the atomic absorption spectrophotometry. P was determined by the method of KOENIG and JOHNSON⁹⁾.

Results and Discussion

Table 2 shows the apparent digestibilities and DCP and TDN contents of the diets and nitrogen balance data. In Experiment 1, average daily intakes of the mixed

Table 2. Apparent digestibilities and nitrogen balance data.

	Experiment 1			Experiment 2
	Diet 1 +hay	Hay	Diet 1	Diet 2 +rice hull
Apparent digestibility	 (%)			
Crude protein	63.3	48.7	77.1	68.4
Ether extract	46.8	52.0	—	83.6
N F E	72.5	58.2	89.1	78.0
Crude fiber	51.3	57.7	—	12.5
Organic matter	66.6	56.9	79.7	65.4
Gross energy	61.6	52.1	79.7	65.4
DCP in dry matter	7.7	4.5	13.0	9.1
TDN in dry matter	58	52	66	52
Nitrogen balance	 (g/day)			
N intake	7.52 ¹⁾	4.03	—	8.26 ²⁾
Excretion	Feces	2.76	—	2.60
	Urine	3.65	—	6.59
N retention	1.11	—0.02	—	—0.93

1) 3.85 g from Diet 1 and 3.67 g from hay. 2) 7.77 g from Diet 2 and 0.49 g from rice hull.

ration were 457 g (183 g for Diet 1 and 274 g for hay) for the first period and 295 g (only hay) for the second period. The negative nitrogen balance and average daily gain of zero were obtained in the second period. These results were due to low DCP and TDN contents of hay used. HARYU and KAMEOKA⁷⁾ have reported that the goats, about 20 weeks old, given the ration containing 4.6% of DCP show depression in body weight gains. In the first period, nitrogen balance was positive and average daily gain was 30 g. Since 51% of the total nitrogen intake came from Diet 1 (85% in the form of urea) and TDN content at fresh matter basis was 48% (58% in dry matter), the utilization of nitrogen in the form of urea was effective. HAMADA *et al.*⁸⁾ have suggested that the inclusion of 1,2-propanediol into the complete ration containing a large amount of rice straw meal can improve the feed conversion ratio. The supplement of molasses, urea and 1,2-propanediol may be beneficial for the utilization of low quality roughage, because low energy and nitrogen contents of total ration can be improved by additional energy of 1,2-propanediol and molasses and additional nitrogen of urea. Average daily intake of the mixed ration in Experiment 2 was 452 g. Of the nitrogen ingested in Experiment 2 over 80% came from urea and over 90% came from non-protein nitrogen. However, toxic effect of urea and scouring were not observed throughout the experiments. It was considered that the liquid diet used in this experiment had a good palatability for the ruminants. The mixed ration used in Experiment 2 contained less available energy for the incorporation of ammonia into microbial protein than that of the mixed ration of Diet 1 and hay. Urinary excretion of nitrogen was two times higher in Experiment 2 than in the first period of Experiment 1, and the nitrogen balance was negative in Experiment 2. This fact showed that ammonia absorbed from the rumen wall was excreted into the urine.

The observation of no toxic symptoms due to urea ingestion and the positive nitrogen balance data of Experiment 1 suggested that the inclusion of 1,2-propanediol into the urea-containing ration may not be suppressive for the urea utilization of the ruminant. Though sulfur content and sulfur:nitrogen ratio affect the utilization of non-protein nitrogen⁸⁾, sulfur content was not measured in these experiments.

Mineral compositions of the rations fed are shown in Table 1. Table 3 shows mineral balance data. The dietary intake of minerals was higher in Experiment 2 than in Experiment 1 except for Mg and K. Of the minerals in the mixed ration of Experiment 2, 97-99% was provided by Diet 2.

In Experiment 1, retentions of Ca and P were improved in the first period compared with the second. Although mineral contents of the mixed ration of Diet 2 and rice hull were higher than mineral requirements of goats, all mineral balances except for Na were negative. In Experiment 1, the goats fed on the mixed ration excreted small amounts of Ca and P into urine. On the contrary, large amounts of Ca and P were excreted into urine in Experiment 2. In both experiments, ratios of fecal excretion to total ingestion of Ca and P were unchanged. Increased excretion of Ca and P in the urine reduced the retention of Ca and P and resulted in severe negative balances of Ca and P. There are individual variations in urinary mineral excretion⁹⁾, but

Table 3. Mineral balance data.

		Ca	P	Mg	K	Na
Experiment 1.	Diet 1 and hay	(g/day)				
Intake	{Diet 1	1.50	0.95	0.53	3.90	2.07
	{Hay	1.07	0.72	0.66	4.87	0.22
Excretion	{Feces	2.46	1.34	1.04	0.38	0.18
	{Urine	0.02	0.00	0.40	7.49	1.74
Retention		0.09	0.33	-0.25	0.90	0.37
Experiment 1.	Hay only					
Intake		1.15	0.77	0.71	6.27	0.24
Excretion	{Feces	1.59	0.61	0.59	0.38	0.07
	{Urine	0.01	0.00	0.22	5.09	0.14
Retention		-0.45	0.16	-0.10	0.80	0.03
Experiment 2.						
Intake	{Diet 2	3.46	2.06	0.94	8.26	2.62
	{Rice hull	0.07	0.02	0.01	0.24	0.05
Excretion	{Feces	3.10	1.58	0.79	0.41	0.12
	{Urine	0.46	0.68	0.29	8.42	2.27
Retention		-0.03	-0.18	-0.13	-0.33	0.28

the goats used in Experiment 2 were the same with the goats used in Experiment 1, so that, large urinary excretion of Ca and P was not due to individual differences. Moreover, Mg balances were negative throughout the experiments.

It is shown that urinary excretion of Ca and P is closely related to urine pH¹⁰⁾, that is, a decrease in urine pH is associated with a marked increase in the urinary excretion of Ca and P. As it is also shown that acidosis decreases the urine pH¹⁰⁾, the goats in Experiment 2 might be suffered from acidosis. Further experiment must be conducted to clarify the relationship between mineral metabolism and the diet used in this experiment.

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1, 2-プロパンジオール, 糖蜜, 尿素, ミネラル・ビタミン からなる液状飼料と粗飼料を給与した 山羊の消化および代謝試験

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1, 2-プロパンジオール, 糖蜜, 尿素, ミネラル・ビタミン混合物からなる液体飼料と乾草あるいはモミ殻との混合飼料の栄養価を求めるため, 去勢した在来山羊を用いて, 消化試験および窒素, ミネラル出納試験を行った。試験1で用いた飼料1では, エネルギー源として1, 2-プロパンジオール 25.4%, 糖蜜 50.8%, 窒素源として尿素 3.8%を含有していた。試験2で用いた飼料2では1, 2-プロパンジオール 28.7%, 糖蜜 57.4%, 尿素 4.4%が含有されていた。試験期間中, 尿素中毒症は認められなかった。粗蛋白質と有機物の見かけの消化率は, 飼料1では, それぞれ, 77.1%, 79.7%, 飼料2とモ

ミ殻の組み合わせ給与時では, 68.4%, 65.4%であった。窒素の蓄積量は飼料1と乾草の混合給与時には1.11 g/日であったが, 飼料2とモミ殻の混合給与時には-0.93 g/日であった。1, 2-プロパンジオール, 糖蜜と尿素的組み合わせ給与により乾草を含めた飼料全体の利用が改善されること, 飼料中の1, 2-プロパンジオールが尿素利用を抑制する可能性のないことが示唆された。カルシウムとリンの出納は飼料1と乾草の混合給与時には正であったが, 試験2では負であった。マグネシウムの出納は試験期間を通して負であった。

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