THE INFLUENCE OF THE ORAL ADMINISTRATION OF SYNTHESIZED NITROGENOUS COMPOUNDS ON THE DIGESTIBILITY COEFFICIENT OF THE DIET

By

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Recently it has been recognized in our country, although known for a long time in America and Europe, that the urea can be utilized as a substitute for protein in the diet of the ruminant. This is not academic, but of practical importance in feeding the domestic animal.

Harris and Mitchell[1] showed that on a diet deficient in nitrogen, only 17.8 per cent of the cellulose was digested, but when supplemented with urea the digestibility increased to 38.7 per cent. Unfortunately this has not been confirmed by subsequent experiments. Hirose[2] has reported on the influence of the oral administration of urea on the digestibility coefficients of nutrients in the rupin hay, and stated that they all show a tendency to slightly increase, especially in the cases of crude fiber and true protein. Tsuda[3] has estimated the cellulolytic power in the rumen of the goat in vivo by the silk bag method and its details are to be published later on. More recently Gallup et al.[4] showed that in their all experiments urea increased the digestibility of the rations.

Thus it is desirable to confirm that the digestibility coefficients of nutrients, especially of crude fiber, are raised, when the diet deficient in protein-nitrogen is supplemented with urea.

Experimental Procedure

The feeds used in this investigation are : orchard grass hay, plain grass hay, wheat bran and soy bean oil meal. Orchard grass, in bloom, and plain grass

are cut, and cured in the sun, being over turned occasionally to insure uniform exposure for about 5 days at the experimental farm of the Faculty of Agriculture, Iwate University. The plain grass mostly consists of miscanthus and the Japanese lespedeza. The hay thus obtained is cut about 1 cm. long by a hand cutter.

Wheat bran and soy bean oil meal are both commercial materials. The latter is manufactured, being pressed by the hydraulic pressure. Besides these feeds two synthesized nitrogenous compounds, that is, urea and ammonium nitrate, are used. They are chemically pure materials, manufactured by Kanto Chemicals Co. Ltd.

Two Sanen male-goats of unknown history which are about one year and three months old and not castrated, are used in this digestion and nitrogen-balance trial. The trial apparatus or metabolism crate used was made by the writers after the one devised by Hodgson[5].

The details of the crate are as follows : the crate has a floor area of 0.9 square meter, a manger and yoke are built at one of its end so that the animal can be stanchioned while eating. Water and salt, containing phoscal (commercial calcium powder), are accessible through the opening in the rear end of the crate. The crate has two false bottoms, one of 2 cm. mesh wire on which the animal stands and through which the excreta pass and another of 0.6 cm mesh wire which catches the feces and permits the urine to pass through. The urine is caught on a funneled pan and conveyed to a glass receptacle. Types of diet used in this trial are shown in Table 1. The digestion trial for each type of diet was 17 days. The preliminary period is 7 days, while the collection period continues for 10 days.

Dates of each period are shown in Table 2. Especially two trials were made, there were divided into former and latter subperiod and each one was numbered as I, II, and III in the digestion trial of goat No. 1.

Table 1. Types of diet used in this trial given by the weight of mixed feed in daily ration.

Feed \ Goat / Period	No. 1			No. 2		
	I	II	III	I	II	III
Orchard grass hay g.	300	370	370	200	235	235
Plain grass hay do.				200	235	235
Wheat bran do.	400	400	400	400	400	400
Soy bean oil meal do.	100	30	30	100	30	30
Urea do.		13			13	
Ammonium nitrate do.			17			17

I : Basal diet period
II : Urea diet period
III : Ammonium nitrate diet period

Table 2. Dates of each period of this trial from July 18 1949 to February 2 1950.

Collection period and subperiod	Goat / Date	No. 1		No. 2	
		From	To	From	To
I	Former	Aug. 8	Aug. 18	Dec. 16	Dec. 26
	Latter	Aug. 26	Sep. 5		
II	Former	Sep. 10	Sep. 20	Jan. 3	Jan. 13
	Latter	Oct. 5	Oct. 15		
III	Former	Oct. 26	Nov. 5	Jan. 23	Feb.2
	Latter	Nov. 5	Nov. 15		

Each feed and a certain synthesized nitrogenous compound are thoroughly mixed before daily feeding in the proportion shown in Table 1.

One-third of the weighed food is fed thrice daily, during which time the animal is fastened in the yoke to avoid losing feed in the crate.

Previously each feed is taken for dry matter and chemical determination. The refused ration is weighed daily and one-tenth of it is sampled for dry matter and chemical analysis.

Feces and urine excreted are weighed daily and 10 per cent of the aliquot sample is respectively saved for chemical analysis. Daily aliquot feces are dried at about 45°C, after 5 per cent solution of H_2SO_4 is suitably sprayed on them to prevent loss of nitrogen by the possible evaporation of various nitrogenous compounds. Daily aliquot urine is, in succession, poured into the glass receptacle containing H_2SO_4. At the close of the collection period daily aliquots of feces and urine are thoroughly mixed and sampled for chemical analysis respectively The analyses of feces and urine are made by the usual methods as outlined in the Japanese manual on the methods of agricultural chemical analysis[6].

In this trial carmine is used to determine both limits of the feces at the collection period. Namely, the collection period is begun when the feces are colored with carmine on the following day after 2 g. of carmine is thoroughly mixed in the ration. Feces colored with carmine are excreted for about 3 days. At the close of the collection period of 10 days the carmine administration is given by the aforementioned method, but at this time the feces colored with carmine are discarded.

Experimental Results

A. *Composition of Feed.*

The chemical composition of each feed used in this experiment is shown in Table 3.

The analysis of the feeds are made by the usual methods. Calcium is volu-

Table 3. Chemical composition of feeds used in this experiment.

Constituent	Orchard grass hay	Plain grass hay	Wheat bran	Soy bean oil meal
Moisture per cent	9.58	13.76	12.84	11.87
Per cent on the dry basis				
Crude protein	11.50	16.80	16.50	55.25
Total-N	1.84	2.69	2.64	8.84
Protein-N	1.54	2.17	2.35	7.82
Non protein-N	0.30	0.52	0.29	1.02
Crude fat	3.21	3.24	4.88	8.10
Crude fiber	21.40	31.51	11.61	5.76
Ash	7.51	8.67	6.91	5.73
Ca	0.59	0.35	0.38	0.41
P	0.21	0.06	1.32	0.77
Nitrogen-free extract	56.38	39.78	60.10	25.16

metrically determined by the use of kalium permanganate after the separation of it as calcium oxalate. Phosphorus is also volumetrically determined, being isolated as the precipitate of ammonium phosphomolybdate from the filtrate which is obtained after the filtration of calcuim oxalate.

B. *Composition of Excrete*

In Table 4 is given the chemical composition of the feces and urine of the animals used in the three metabolism trials. The nitrogen determination in

Table 4. Chemical composition of ieces and urine receiving rations of three periods.

Goat No. 1

material analysed	Constituent \ Period and subperiod	I		II		III	
		Former	Latter	Former	Latter	Former	Latter
Feces	Moisture per cent	14.22	11.32	12.91	10.59	15.73	15.67
	Per cent on the dry basis						
	Crude protein	11.30	10.98	11.63	13.23	11.46	11.85
	Total-N	1.81	1.76	1.86	2.11	1.84	1.90
	Protein-N	1.62	1.61	1.50	1.51	1.38	1.55
	Non protein-N	0.19	0.15	0.36	0.60	0.46	0.35
	Crude fat	5.39	5.76	2.89	3.25	3.14	4.19
	Crude fiber	28.34	25.14	24.43	23.76	31.86	32.29
	Ash	12.40	11.33	11.34	11.01	11.90	12.47
	Nitrogen-free extract	42.57	46.79	49.70	48.75	41.63	39.20
Urine	Nitrogen Vol. per cent	1.59	1,29	1.62	2.04	1.99	1.78

Goat No. 2

Feces	Moisture per cent	7.06	10.05	10.32
	Per cent on the dry basis			
	Crude protein	14.05	15.99	15,08
	Total-N	2.25	2.56	2.41
	Protein-N	2.16	2.06	1.85
	Non protein-N	0.09	0.50	0.56
	Crude fat	6.28	3.97	4.48
	Crude fiber	26.52	25.84	29.74
	Ash	13.96	13.16	13.39
	Nitrogen-free extract	39.19	41.04	37.31
Urine	Nitrogen vol. per cent	1.63	2.42	2.75

the feces and urine of ammonium nitrate diet period is made by the Gunning's modification method, as it is thought that the nitrate-type nitrogen may be, though not identified, contained in them.

C. *Apparent Digestibility of Nutrients*

In Table 5 is shown the live weight of each animal on each of the rations. As shown in the table each goat is inclined to suffer a loss rather than make any gain in live weight during each digestion trial. Table 6 contains the data on the organic matter and nutrients ingested, voided, and digested by the goats receiving different rations. Table 7 shows the apparent digestibility in each period of each goat.

D. *Nitrogen Balance*

The data pertaining to the nitrogen balance of each goat receiving different rations are given in Table 8.

Table 5. Live weight of each goat in relation to individual rations.

Goat	Period and subperiod	Collection period	Initial kg.	Final kg.	Gain kg.
No. 1	I	Former	29.0	29.0	0
		Latter	29.0	30.0	1.0
	II	Former	31.0	30.0	—1.0
		Latter	30.5	29.0	—1.5
No. 2	III	Former	31.0	30.5	—0.5
		Latter	30.5	29.5	—1.0
	I		30.5	31.0	0.5
	II		32.0	30.5	—1.5
	III		30.5	30.5	0

Table 6. Organic matter and nutrients ingested, voided, and digested during a 10-day period by goats receiving rations of basal diet, urea diet and ammonium nitrate diet.

Goat No. 1

Period & subperiod		Constituent / Weight g.	Organic matter	Crude protein	True protein	Crude fat	Crude fiber	Nitrogen-free extract
I	Former	Fed	6585.3	1374.1	1203.7	328.4	1036.1	3846.7
		Refused	371.5	27.7	20.4	7.2	116.7	134.3
		Consumed	6213.8	1346.4	1183.3	321.2	919.4	3712.4
		Voided	2810.5	362.8	325.4	172.6	908.9	1366.1
		Digested	3403.3	983.6	857.9	148.6	10.5	2346.3
	Latter	Refused	17.8	1.7	0.6	0.1	5.9	8.3
		Consumed	6567.5	1372.4	1203.1	328.3	1030.2	3838.4
		Voided	2492.9	308.9	283.2	161.8	707.3	1314.7
		Digested	4074.6	1063.5	919.9	166.5	322.9	2523.7
II	Former	Consumed	6719.1	1485.3	963.0	298.7	1136.0	4048.4
		Voided	2779.6	364.8	296.1	91.2	766.4	1558.1
		Digested	3939.5	1120.5	666.9	207.5	369.6	2490.3
	Latter	Voided	2824.7	420.1	298.7	103.4	753.7	1547.3
		Digested	3894.4	1065.2	664.3	195.3	382.3	2501.1
III	Former	Consumed	6589.1	1478.0	963.0	298.7	1136.0	4048.4
		Voided	2598.2	337.9	252.8	93.4	939.7	1227.8
		Digested	3990.9	1140.1	710.2	205.3	196.3	2820.6
	Latter	Voided	2399.5	324.9	267.1	115.4	884.9	1074.5
		Digested	8189.6	1153.1	695.9	183.3	251.1	2973.9

Goat No. 2

I	Consumed	7324.2	1559.9	1350.4	355.2	1386.0	4023.1
	Voided	3118.7	509.3	489.5	227.8	961.4	1420.4
	Digested	4205.5	1050.6	860.9	127.4	424.6	2602.7
II	Consnmed	7441.0	1685.3	1120.3	325.2	1513.2	4166.4
	Voided	3241.7	596.8	479.7	148.2	964.5	1532.2
	Digested	4199.3	1088.5	640.6	177.0	548.7	2634.2
III	Consumed	7311.0	1678.1	1120.3	325.2	1513.2	4166.4
	Voided	3262.3	567.8	436.0	168.8	1120.1	1510.8
	Digested	4048.7	1110.3	684.3	156.4	383.1	2655.6

Discussion

1) As shown in Table 1, the urea or ammonium nitrate as synthesized nitrogenous compounds is mixed in the proportion of 3 or 4 per cent of the total concentrated feeds in the ration, in which the content of crude protein amounts to 17 or 18 per cent. These are administrated with soy bean oil meal in both diets. It is said that no urea should be administrated with soy bean or soy bean oil meal. In our experiment both goats maintained their usual health,

Table 7. Apparent digestibility (per cent) during each period for each goat.

Goat	Period and subperiod		Organic matter	Crude protein	True protein	Crude fat	Crude fiber	Nitrogen-free extract
No. 1	I	Former	55	73	73	46	1	63
		Latter	62	78	77	51	31	66
	II	Former	59	75	69	70	33	62
		Latter	58	72	69	66	34	62
	III	Former	61	77	74	69	17	70
		Latter	64	78	72	62	22	73
No. 2	I		57	67	64	36	31	65
	II		56	65	57	54	36	63
	III		55	66	61	48	25	64

Table 8. Nitrogen balance of each goat during each period.

Goat \ Period and subperiod — Nitrogen g.			Ingested	Voided			Retained
				Fece	Urine	Total	
No. 1	I	Former	215.4	58.1	138.3	196.4	19.0
		Latter	219.6	49.4	122.6	172.0	47.6
	II	Former	237.7	48.4	128.8	177.2	60.5
		Latter	237.7	67.2	167.3	234.5	3.2
	III	Former	236.5	53.1	151.2	204.3	32.2
		Latter	236.5	52.0	144.2	196.2	40.3
No. 2	I		249.6	81.5	96.2	177.7	71.9
	II		269.6	95.4	260.4	355.8	—86.2
	III		268.5	90.8	152.4	243.2	25.3

except for the increase of urine volume at the 2nd period in the case of goat No. 2. It is thus inferred that the feeds are mixed daily immediately before the administration to the goats and because soy bean oil meal used is manufactured by the hydraulic pressure method, the urease may be almost destroyed.

2) With commencement of the urea diet period of the goat No. 2 the volume of urine increases to about 1000 ml. daily, in spite of the average volume being about 600 ml. daily for the basal diet period. On reaching the ammonium nitrate diet period, the urine increase equals that of the basal diet period. Besides this increase of urine volume and the loss of the live weight (Table 5), the goat maintains his usual health at the urea diet period. Although the reason is unknown, it is certain that the administration of urea in the diet may be attributed this accident. The nitrogen loss only at the 2nd period of the goat No.2 (Table 8) is due to the increase of total volume of urine at this period, considering the fact that the contained nitgrogen content is 2.42 vol. per cent.

3) The nitrogen of the goat fur, adhering to the feces, is determined by the Kjeldahl method to be 5.9 mg. per 100 g. of the feces. The nitrogen in the urine of the goat No. 2, daily adhering on the funneled pan, is also determined; the average for 5 days being 0.15g. during the basal diet period, 0.45 g. during the urea diet period and 0.28 g. during the ammonium nitrate diet period. As shown in Table 8, the daily volume of urine during the 2nd period is the greatest of the total three periods. Thus it is thought that the weight of nitrogen, adhering on the pan, is proportional to the volume of urine. As carmine is used to determine the limit of the feces at each collection period, its nitrogen content is determined to be 33.8 mg. per 1 g. This very small content of nitrogen may be omitted from calculation.

4) At the beginning of this trial, the animals which were fed green herbage ad lib. gradually exchanged for the basal diet (Table 1), and the preliminary period continued for about 20 days. Despite of this arrangement, a part of the diet, especially almost of hay, is refused at the former subperiod of I and the apparent digestibility of crude fiber is only 1 per cent as shown in Table 7. It is thought that the digestibility coefficient of crude fiber is inclined to lessen for some time when the diet changes from green herbage to hay in late autumn.

No diet is refused during the 1st period of the goat No. 2 as shown in Table 6, probably owing to that the animal had previously passed the preliminary period of over one month.

As shown in Table 7, the apparent digestibility of crude fat during the urea diet period and during the ammonium nitrate diet period is superior to that of the basal diet period and the apparent digestibility of true protein of first mentioned diet period is inferior to that of both the basal diet period and the ammonium nitrate diet period. The crude fat in the feces contains various substances, especially bile and related compounds. Accordingly it is questionable whether the crude fat in the diet may be digested in great amount by oral administration of urea or ammonium nitrate.

The apparent digestibility of crude fiber is inclined to be slightly raised by the administration of urea and, on the contrary, is decreased by the administration of ammonium nitrate in the case of both goats. It seems certain that ammonium nitrate has an undesirable influence on the apparent digestibility of crude fiber. It is thought that the microorganism in the rumen may be injured to some degree by their activities owing to the nitrite compounds which have their origin in the reduction of ammonium nitrate.

5) The question is raised whether the rations fed to the goats are sufficient to meet their requirements of maintenance for digestible nutrients. Table 9 shows the digestible nutrients, nutritive ratio, protein ratio and total digestible nutrients (T. D. N.) of the rations fed to each goat. Comparing with the require-

ments per head daily shown in the section of growing ram lambs and yearlings by the Morrison feeding standards,[5] each goat is insufficiently fed dry matter, T. D. N. and digestible protein, except for the digestible true protein during the basal diet period (Table 9). Whether the two synthesized nitrogenous compounds used may be effectively utilized and supplement the protein in the diet cannot be concluded from the present experiment.

Table 9. Digestible nutrients, nutritive ratio, protein ratio and T.D.N. of the rations.

Goat	Period	Crude protein g.	True protein g.	Crude fat g.	Crude fiber g.	N.F.E. g.	Nutritive ratio	Protein ratio	T.D.N. g.
No. 1	I*	107.2	92.7	16.7	32.1	253.9	3.0	3.6	431
	II	109.9	66.4	20.3	38.6	251.0	3.0	5.7	445
	III	115.3	70.3	19.7	22.7	283.4	3.0	5.6	466
No. 2	I	104.5	86.4	12.8	43.0	261.5	3.2	4.1	438
	II	109.5	63.8	17.6	54.5	262.5	3.3	6.3	466
	III	110.7	68.3	15.6	37.8	275.0	3.1	5.7	459

* These values are calculated by using the apparent digestibility during the latter subperiod.

Summary

The digestive and nitrogen balance trials were conducted to determine the influence of the oral administration of the two synthesized nitrogenous compounds, i.e. urea and ammonium nitrate on the digestibility coefficient of the diet, using two Sanen male-goats as the trial animal.

The percentage of apparent digestibility of the diet constituents in the different rations were : the average in the basal diet, in the urea diet and in the ammonium nitrate diet were respectively 60, 58, 59, for crude organic matter, 73, 70, 72 for crude protein, 71, 63, 67 for true protein, 44, 61, 57 for crude fat, 31, 35, 23 for crude fiber, and 66, 63, 68 for nitrogen-free extract. The positive balance of nitrogen is maintained by the goats receiving the three different rations, except for the case of goat No. 2 in the urea diet. Under the conditions of this experiment, it may be said that the apparent digestibility of crude fiber is inclined to be slightly raised by the oral administration of urea and decreased by ammonium nitrate.

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