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## Diurnal Changes in the Composition of Abomasal Digesta in Fasted and Fed Sheep

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### Summary

1) To know the possibility of participation of the lower intestinal tract on the control of feed intake in sheep, the nature of digesta flowed out from the abomasum was measured over 24 hours in fasted and fed animals fitted with the single T-shaped duodenal cannula.

2) The digesta flow rate and dry matter contents in the fasted sheep decreased to 30 per cent and 28 per cent respectively of those of fed sheep. Though the patterns of digesta flow in a day were different between the fed and fasted sheep, the tendency of increase of flow rate toward the feeding time the next morning was the same in both conditions.

3) The increase in digesta flow rate coincided with the increase of VFA concentrations in digesta in both experiments.

4) It may be worth noting that when the sheep stopped eating, the highest values were observed both in the flow rate of digesta and in the total VFA concentration in the digesta.

To understand the control mechanisms of feed intake in the ruminants is of great importance in improving the efficiency of their productivity.

In the ruminants, both the concentration of volatile fatty acids (VFA) in the rumen (1) and the mechanical ruminal distention of the rumen (2) have been considered as the satiety signals which work on the regulatory center of the voluntary feed intake. These factors have been investigated intensively as a ruminal factor in the control mechanism of feed intake. There is, however, little report on the role of the lower digestive tracts in the control of feed intake.

It is regarded in monogastric animals that the digesta entered into the duodenum regulates the feed intake with their own chemical or physical properties through the route of hormonal or neural pathways (3~6).

Sensory receptors in the alimentary tract were discussed intensively, including the nature of epithelial receptors (mechano- and chemo-receptors) located in

the duodenum (7). Therefore, the possibility of the participation of the lower gut in the control of feed intake in the ruminant could not be excluded.

Before studying the effects of the lower digestive tract on the feed intake in sheep, it seems necessary to know the natures of digesta flowed out from the abomasum. Therefore, the volume, flow rate and components of digesta from the abomasum were preliminarily investigated over 24 hours in fasted and fed sheep.

### Materials and Methods

Two wethers weighing 44.5 and 67.5 kg were used. They were fitted with the single T-shaped cannula which was placed in the duodenum 4 to 6 cm distal from the pyloric sphincter, and was exteriorized on the right side of the abdomen just behind the last rib. Surgical cannulation followed the procedure of Komarec (8).

Collection of the digesta flowed out from the abomasum: the balloon catheter (Terumo, SF-BR2605D, length: 42 cm) was inserted into the distal side of the cannula, and the balloon was inflated in order to stop the digesta flow into the lower part of the duodenum. The digesta from the abomasum was forced to flow out through the stem part of the cannula by this procedure.

Return of the digesta to the animal: The collected digesta which was warmed at 40°C in a water bath while mixed with a stirrer, was returned to the duodenum by a bellows pump (Nikkisou, M-20026.2). The rate of return of digesta was adjusted to be the same as that of the flow out.

A hay cube was given at 11:00 a.m. and was withdrawn when the sheep stopped eating for 15 continuous minutes. For this situation we said that the sheep reached the "satiety state". The sheep was accustomed to this feeding protocol for at least two weeks.

In Exp. 1, the sheep was starved for 24 hours. In Exp. 2, the sheep was fed the same as in the accustoming period.

On the day of experiment, the sheep was inserted with the balloon catheter in the duodenum through the T-shaped cannula at 8:30 a.m. The measurements were started at 9:30 a.m. and continued until 9:30 a.m. the next morning.

After measuring the volume of the digesta flowed out from the abomasum in every 30 minutes, about 10 ml of specimen was sampled from each digesta to examine the pH, dry matter content and VFA concentrations. The rest of the digesta was returned into the duodenum.

The amount of feed intake and the length of intake period were measured in Exp. 2. The concentrations of VFA were measured by the gaschromatography (YANAKO, G-80, column length: 2.25 m, column packing: FAL-M).

Results are expressed as the means of six observations that were obtained from three repeated experiments with two animals.

## Results

*Exp. 1:* The results of the flow rate, dry matter percentage and pH of digesta in the fasted sheep are shown in Fig. 1. The digesta flow rates are expressed as the mean value of every 30 minutes. The average value from 9:30 a.m. to 11:00 a.m. was  $3.49 \pm 1.25$  ml/30 min·kg (means  $\pm$  SD), and the value decreased until 4:00 p.m. with continuous low flow rate. In the next morning, the flow rate began to increase with the average value of  $2.04 \pm 1.58$  ml/30 min·kg between 7:30-9:30 a.m. This value is 58.5 per cent of that obtained between 9:30-11:00 a.m. in the preceding day. The total amount of digesta flow for 24 hours was  $3797 \pm 1298$  ml. The dry matter percentage gradually decreased to reach the lowest level of 2.3 per cent at 1:00 a.m. and then returned to almost the

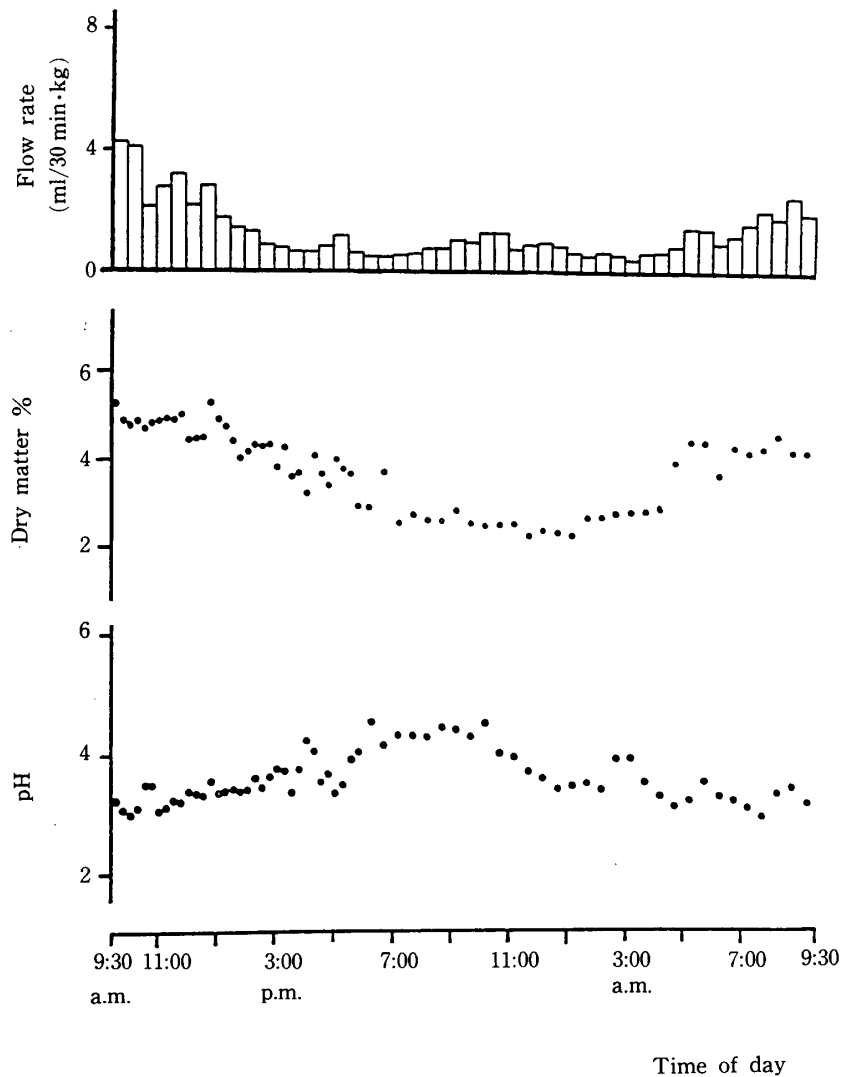


FIG. 1. The diurnal changes in flow rate, dry matter percentage of digesta flowed out from abomasum in fasted animals. Values are expressed as the mean of six observations.

same level as the initial level obtained at the start of the experiment.

The value of pH increased gradually toward the middle of the experimental period. The mean value during 9:30–11:00 a.m. was  $3.2 \pm 0.04$ , and that during 7:00–9:00 p.m. was  $4.3 \pm 0.25$ . Then it decreased slowly to the same level as that of when the experiment started.

The changes of total VFA concentration and their molar percentages of digesta are shown in Fig. 2. From one hour after the start of the experiment, the total VFA concentration decreased continuously until 4:00 p.m. After 3:00 a.m., it slowly increased toward the initial level. The molar ratio of acetate, propionate and butyrate was maintained at the initial proportion throughout the day except for a little increase of acetate during the middle of the night.

*Exp. 2:* The pattern of feed intake is shown in Fig. 3. The time required to reach the "satiety state" was  $238 \pm 34$  min. Total feed intake was  $1515 \pm 385$  g. The sheep ate at a high rate immediately after the start of feeding and consumed about 48 per cent of their total feed intake within one hour.

The results of the measurements of the flow rate, dry matter percentage and pH of digesta are shown in FIG 4. The total digesta flow for 24 hours was  $12675 \pm$

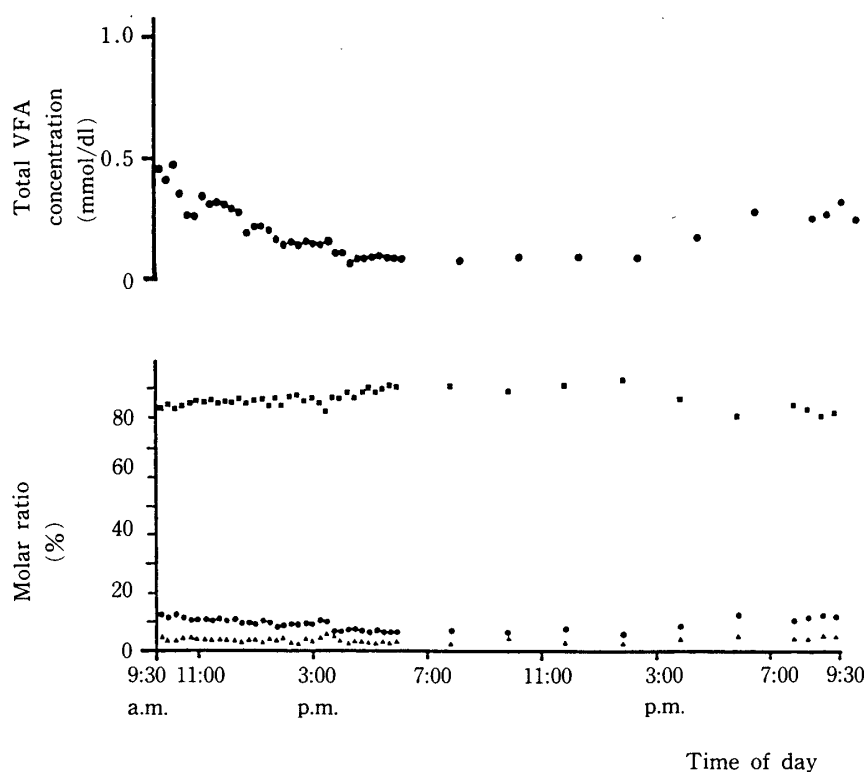


FIG. 2. The diurnal changes in total VFA concentration and its molar ratios in the digesta flowed out from abomasum in the fasted animals. In the bottom figure, the symbols (■, ●, ▲) represent the molar ratio of acetate, propionate and butyrate, respectively. Values are expressed as the means of six observations.

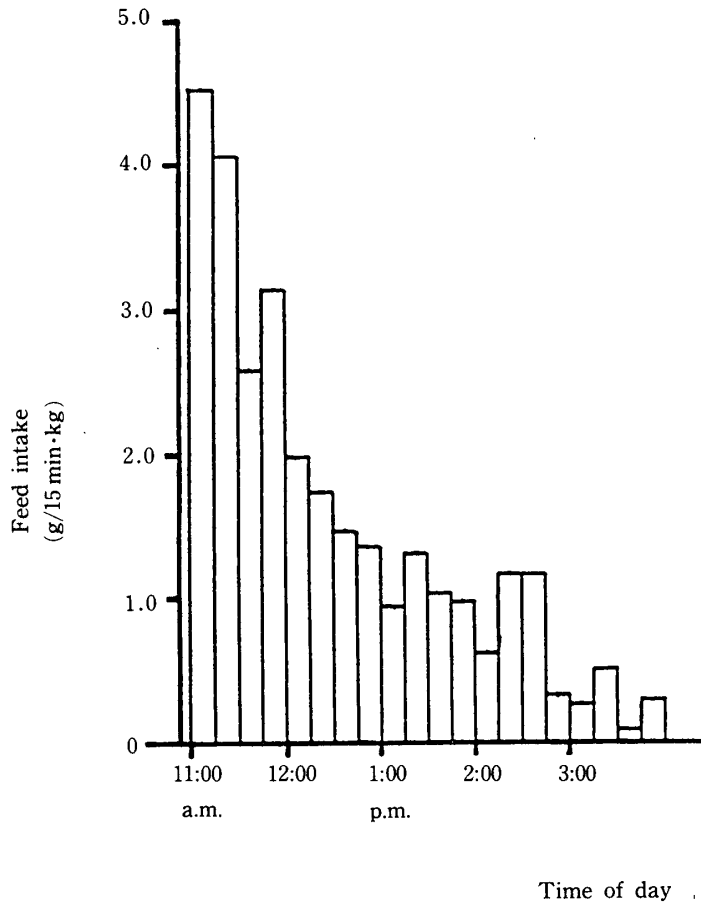


FIG. 3. The pattern of feed intake in the fed animals. Values are expressed as the means of six observations.

3828 l. The flow rate during 9:30–11:00 a.m. was  $6.04 \pm 3.02$  ml/30 min·kg and increased gradually to reach the maximal value of  $15.38 \pm 9.44$  ml/30 min·kg during 2:30–3:00 p.m. Then the digesta flow decreased slowly toward the minimum value,  $2.52 \pm 3.24$  ml/30 min·kg, around 3:00 a.m. It showed a tendency to increase again toward the subsequent feeding time the next morning.

The dry matter percentage before feeding was  $4.4 \pm 1.1$  per cent, followed by the decrease after feeding until 5:00 p.m. After that time, it increased above 5 per cent and kept the same level thereafter.

The pH of digesta fluctuated a little with a tendency to decrease toward the feeding time the next morning.

FIG 5 shows the results of total VFA concentration and their molar ratio. The total VFA concentration of digesta started to increase with the beginning of feed intake and reached the highest concentration in the period of 2:30–6:00 p.m. Then it decreased to the initial level the next morning. The molar ratios of acetate, propionate and butyrate before feeding were 85, 10 and 5 per cent respectively. The percentage of acetate slightly decreased to 80 per cent which was

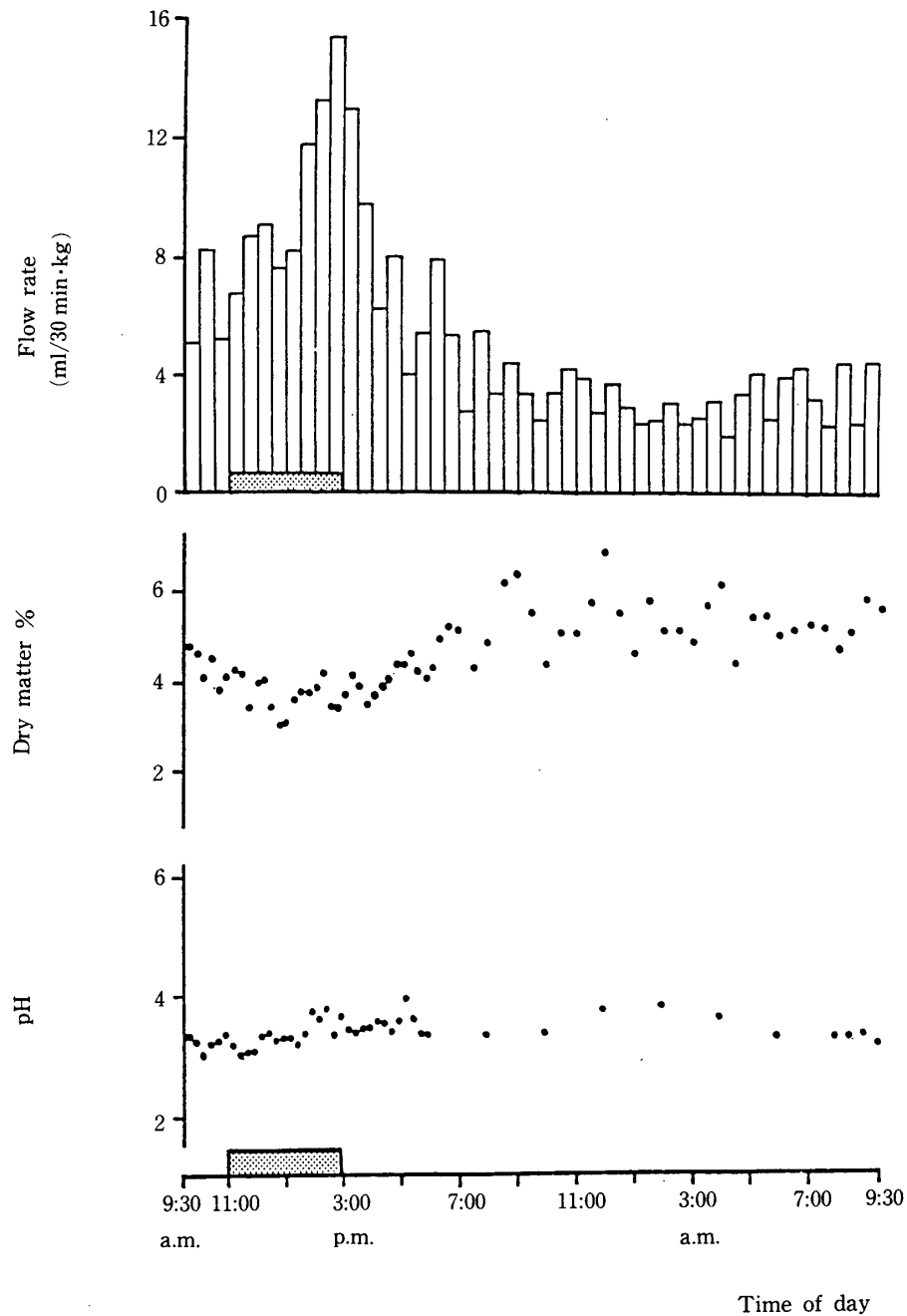


FIG. 4. The diurnal changes in flow rate, dry matter percentage and pH of digesta flowed out from abomasum in the fed animals. Values are expressed as the means of six observations. Both dotted areas indicate the feeding period.

replaced by 5 per cent increase of propionate after the start of feeding. In the night, those ratio returned to the same level as before feeding.

### Discussion

In the fed animals, the total outflow of digesta from the abomasum in a day

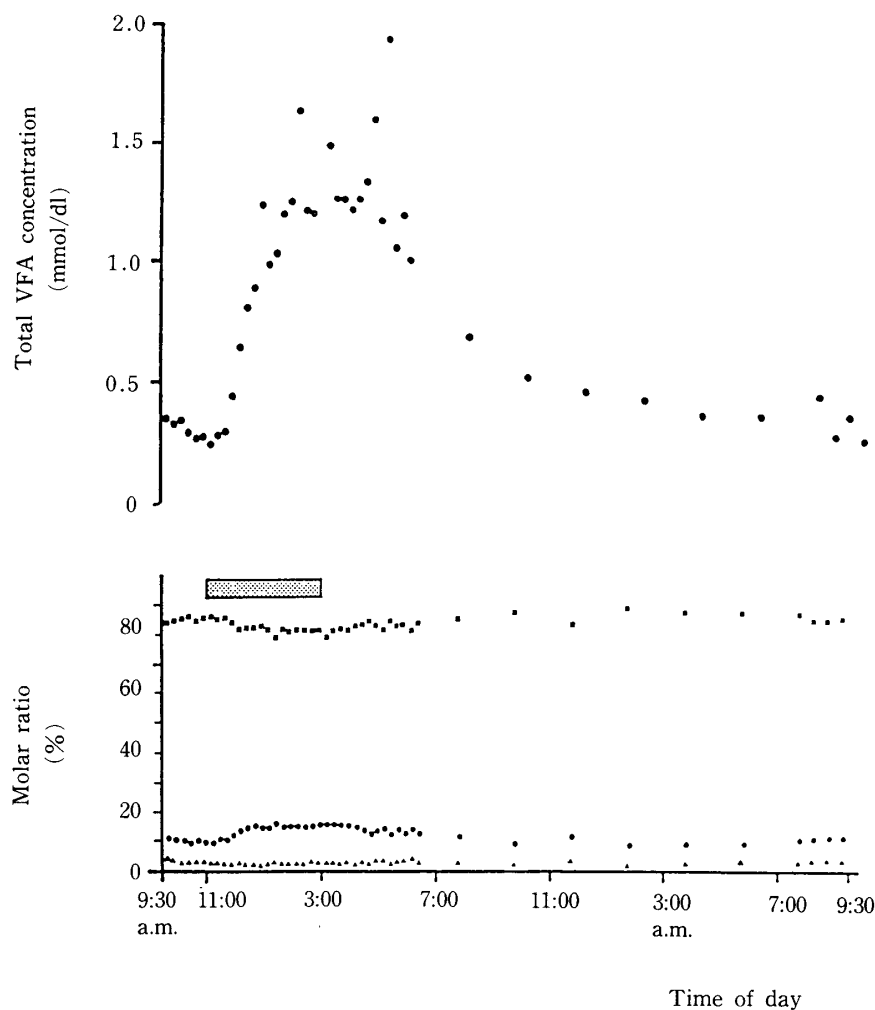


FIG. 5. The diurnal changes in total VFA concentration and its molar ratios in the digesta flowed out from abomasum in the fed animal experiment. In the bottom figure, symbols (■, ●, ▲) represent acetate, propionate and butyrate, respectively. Values are expressed as the means of six observations. The dotted area indicates the feeding period.

was 12675 ml, which was slightly high compared with the reported value of 8.5–11.0 *l*/day (9). The total dry matter weight in the outflowed digesta was 592.8 g/day. This means that 45.05 per cent of dry matter ingested per day was apparently flowed into the duodenum since the animals ingested 1318.4 g of dry matter (the dry matter percentage of hay cube was 87.02 per cent).

In the fasted animals, the total amount of the outflowed digesta from the abomasum decreased to about 30 per cent of that of the fed animals. The weight of total dry matter in the outflowed digesta was 166.9 g/day which was only 28 per cent of that of the fed animals.

In the fasted animals, the color of the digesta stayed light brown throughout the day. In the fed animals, however, the color of the digesta became green 6



hours after feeding and then returned gradually to the light brown (PLATE 1-A, B). The color changes of the digesta to green and to light brown coincided with the increase and decrease of the dry matter percentages in the digesta respectively. Because the ground hay was more rapidly excreted than the long hay (10), the digested fine particles may pass through the digestive tract more smoothly than

絶食時第四胃流出物

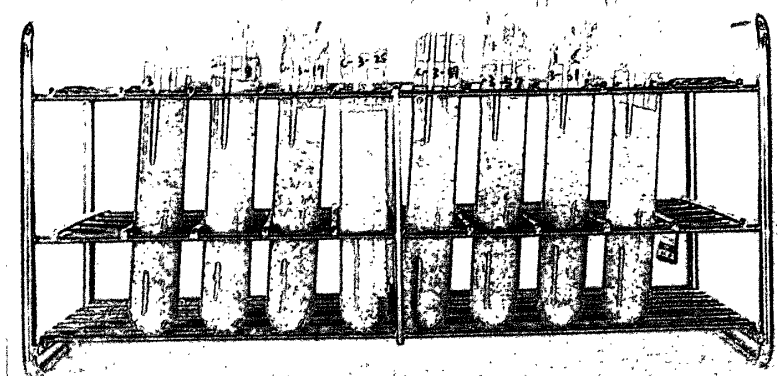


PLATE 1-A (top)

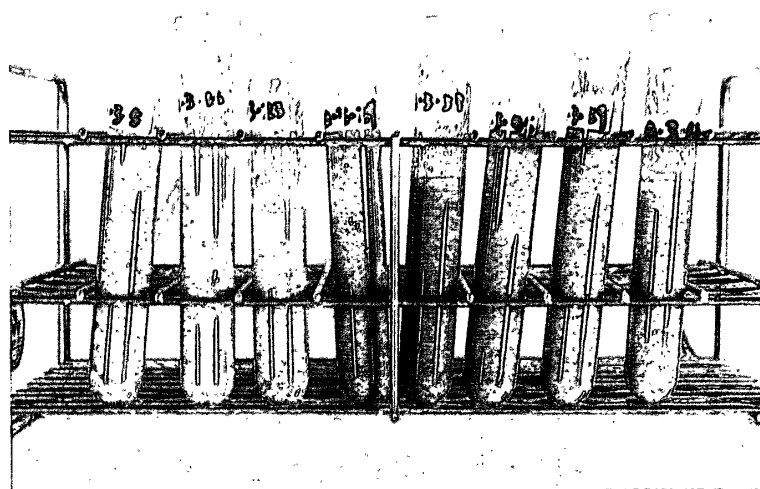


PLATE 1-B (bottom)

PLATE 1-A (top): The typical picture of the color change of digesta flowed out from the abomasum in a fasted animal. These samples were taken at 9:45, 11:45 a.m., 1:45, 3:45 p.m., 1:30, 5:30, 7:30, 9:30 a.m., respectively from left to right.

B (bottom): The typical picture of the color change of digesta flowed out from the abomasum in a fed animal. These samples were taken at 10:45 a.m., 1:30, 3:15, 4:45, 8:30, 11:30 p.m., 6:30, 8:30 a.m., respectively from left to right.

the non digested feeds. It is likely that for several hours after the start of feeding the large parts of the outflowed digesta mainly consisted of the feed which was consumed a day before the experiment. From about 6 hours after feeding the digesta began to contain the feed which was eaten on the day of the experiment. It could be assumed that the rate of digestion of the feed might be reflected in the color of the digesta.

The dry matter percentage of the digesta decreased with the decrease of the flow in the fasted animals. On the other hand, the dry matter percentage decreased when the rate of flow increased in the fed animals. It might be explained that in the fasted animals, a relative increase of water percentage in the digesta resulted, due to the decrease of the dry matter weight of digesta with the constant secretion of gastric fluid from the abomasum. The values observed in the fed animals might be due to the increases of the amounts of saliva secretion (11) and of drunk water (12). The dry matter percentages in the present experiments in the fed animals were within the reported range of 3-5 per cent (9) and 4.1 per cent (13).

The pH of the digesta did not change and was in the range of 2-3 which was the same as that already reported (9). In the fasted animals in the present experiment, however, pH of the digesta exceeded the value of 4 during the early night.

The change in VFA concentration accorded with that of the flow rate of digesta in both fasted and fed animals. The range of VFA concentration in the rumen digesta was reported from 2.9 to 6.6 mmol/dl (14). In the present experiment, the lowest concentration of VFA in the digesta flowed out from the abomasum was 0.07 mmol/dl in the fasted animals. In the fed animals, the highest and lowest concentration, were 2.1 and 0.25 mmol/dl. These values were from one-tenth to one-third of that observed in the rumen, and were consistent with the report by Phillipson & Ash (9).

In the rat, the digestive enzymatic activities increased toward the coming feeding time because of their abilities to learn the feeding schedule in a day (15). In our experiments, the flow rate of digesta, dry matter percentage and VFA concentration in the digesta tended to increase while pH tended to decrease toward the next feeding time. These phenomena might be due to an increase of the activity and motility of the forestomach, which was induced by learning to know the feeding schedule as shown in the rat. The detail of the mechanism is unclear because the motility of forestomach and other factors necessary to confirm this hypothesis were not measured in the present experiment.

In the fed animals, the digesta flow was maximum and the VFA concentration in the digesta was highest when the animals stopped eating. It might be likely that some physiological relationship would exist between the cease of intake and the several changes in the digesta observed in the present experiment.

It would be the subject for further investigation.

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