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The Effects of the Constantly Maintained Ruminal pH on the Parotid Saliva Secretion of Sheep

Yoshiaki OBARA*, Yasushi OHTOMO, and Tsuneyuki TSUDA

Department of Animal Science, Faculty of Agriculture,
Tohoku University, Sendai, Japan

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Summary

1. The salivary flow from the unilateral parotid gland of sheep was measured while the pH of rumen fluid was maintained at 5 or 6 for three hours by the administration of acetic, propionic, butyric or hydrochloric acid into the rumen.

2. The rate of parotid secretion showed a tendency to decrease when the ruminal pH was lowered to 5 by the administration of propionic and buryric acid. The decrease was more obvious in the case of butyric acid introduction. As the pH recovered to the pre-experiment range, the flow rate also returned to the control level. On the contrary, acetic acid administration did not affect the flow rate.

3. When the ruminal pH was maintained at 6 with the addition of acetic, propionic or butyric acid, the resultant saliva flow rate change was an increase, no change and a decrease, respectively.

4. Hydrochloric acid administration did not affect the flow rate although a decrease was observed after the recovery of the ruminal pH.

The main inorganic salt in ruminant saliva is sodium bicarbonate, which is the important factor in neutralizing volatile fatty acids (VFAs) produced in the reticulo-rumen and in maintaining constant rumen ionic composition. Whether or not changes of rumen properties induce changes in the salivary flow is an interesting and still unsolved problem. On this point, the effect of the addition of VFA solution to the reticulo-rumen on the rate of saliva secretion has been studied by several groups of workers (1–4), but those experimental results were conflicting. The present authors have already observed changes in the salivary flow from the unilateral parotid gland of sheep during the course of pH recovery after it had been lowered to 5 at the start of the experiment by a single administration of VFAs or HCl solution. The main results indicated that the secretion rate had a tendency to decrease for 30 minutes after the administration of VFAs, followed by an increase during the next 1–2 hours (5). The present investigation was

* Present address: Fourth Research Division, National Institute of Animal Health, Kodaira, Tokyo, Japan.

designed to inquire into the relation between the parotid saliva secretion and the rumen pH which was lowered by the addition of VFAs or HCl.

Experimental procedure

A female sheep with a permanent unilateral parotid fistula and a ruminal fistula was used in this experiment. Her body weight was maintained at 32 kg by daily feeding of 400 g of hay, 300 g of the commercial concentrate for dairy use and 50 g of sodium bicarbonate which was sufficient to compensate for the loss of sodium from the parotid saliva through the fistula.

The sheep was trained to not bleat and not become excited during the expriments. The experiments were always started on the 41st hour after feeding in order to make the ruminal environment as constant as possible and to ensure that the rumen content was as fluid as possible for easy mixing with the introduced solution. At 15.5 hours before starting the experiment, the animal was only given 50 g of sodium bicarbonate mixed with 100 g of commercial concentrate to offset the loss of sodium from the saliva. The parotid saliva flowing out from the parotid fistula was collected for every 30 minutes through a stainless funnel into a beaker and the volume was measured. The control flow rate was checked for one hour before each treatment. One of the following warmed acid solutions, 0.5 M acetic, propionic, butyric or hydrochloric acid was introduced into the reticulo-rumen to reduce the ruminal pH to 5 or 6. The rumen pH was maintained for 3 hours by dripping the acid solution into the rumen whenever the pH was above from the planned level. The experiment was continued until the rumen pH returned to the initial level after the maintenance period was over.

The ruminal pH was automatically recorded with an electric polyrecorder (Towa EPR–2T type) connected with a glass electrode which was directly inserted into the rumen.

Total VFA concentrations in the rumen fluid were determined by Conway's micro-diffusion technique.

The qualitative analysis of ketone body and the pH of the urine were determined to estimate the level of the ketosis and acidosis influenced by acid infusion into the rumen.

Results

As control experiment, the changes of the rate of saliva secretion, the ruminal pH and the total VFA concentration in the rumen content were observed during the period from the 41st to the 46th hour after feeding. The mean value of the salivary flow without acid infusion was 50.2 ± 8.9 ml/30 min.. The average total VFA concentration and the pH in the rumen throughout the experiment were 32 mM and 7.2, respectively. The change in the salivary flow rate during the acid administration to the rumen was judged from this average.

Figure 1 shows the changes of salivary flow while the ruminal pH was maintained at 6 by the addition of each VFA into the rumen. The dotted line shows the mean value±standard deviation of the salivary flow rate in the control experiment.

The amount of VFA used to reduce the ruminal pH to 6 at the start of the experiment were 0.15, 0.10 and 0.25 moles in acetic, propionic and butyric acids, respectively. The total amount of acid used to reduce the ruminal pH to 6 and maintain it for three hours were 0.40, 0.25 and 0.45 moles in acetic, propionic and butyric acids, respectively.

In acetic acid administration, the saliva secretion rate indicated a tendency to increase. The addition of propionic acid had no obvious effect on the salivary secretion rate during the rumen pH maintenance period. In butyric acid administration, the saliva secretion rate indicated a tendency to decrease by degrees and returned to the control level with the recovery of the ruminal pH.

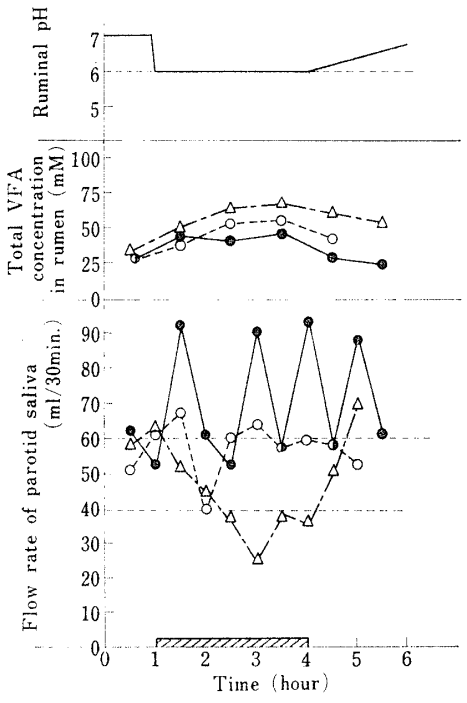

Fig. 1

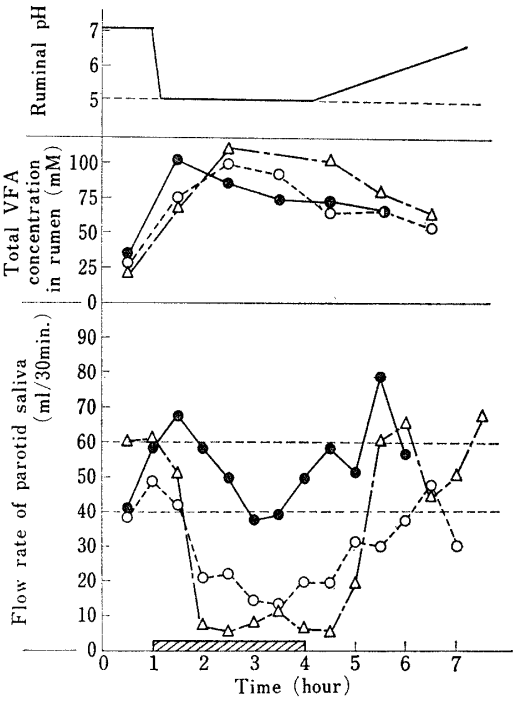

Fig. 2

FIG. 1 Changes of the unilateral parotid salivary flow and the ruminal conditions while the rumen pH was maintained at 6 for 3 hours (1–4 hour) by the administration of acetic (●), propionic (○) and butyric acid (△) to the rumen.
The total amount of acetic, propionic and butyric acid administered into the rumen were 0.40, 0.25 and 0.45 moles, respectively.

FIG. 2 Changes of the unilateral parotid salivary flow and the ruminal condition while the rumen pH was maintained at 5 for 3 hours (1–4 hour) by the administration of acetic (●), propionic (○) and butyric acid (△) into the rumen.
The total amount of acetic, propionic and butyric acid administered into the rumen were 0.70, 0.88 and 0.70 moles, respectively.

Figure 2 shows the changes of the salivary flow when the ruminal pH was maintained at 5 by the addition of each VFA into the rumen. The amount of VFA used to reduce the ruminal pH to 5 at the start of the experiment were 0.45, 0.40, and 0.40 moles in acetic, propionic and butyric acids, respectively. The total amount of acid used to reduce the ruminal pH to 5 and maintain it for three hours were 0.70, 0.88 and 0.70 moles in acetic, propionic and butyric acids, respectively. The amount of each VFA used to maintain the ruminal pH at 5 was twice or more than that at pH 6.

With acetic acid administration, the total VFA concentration in the rumen fluid increased rapidly after the first infusion and maintained a level of about 75 mM during the pH 5 maintenance period. The addition of acetic acid had no obvious effect on the rate of saliva secretion. The amount of propionic acid needed to maintain the ruminal pH at 5 was the largest among the three VFA. In propionic acid administration, the salivary flow began to decrease the first hour after infusion and the low secretion level continued for about three hours. It returned to the normal level when the pH maintenance infusion was stopped. During the acid infusion period, the inhibition of rumen motility were observed.

The amount of butyric acid needed (0.70 moles) to maintain the ruminal pH at 5 was the same as that of acetic acid and the VFA level increase in the ruminal

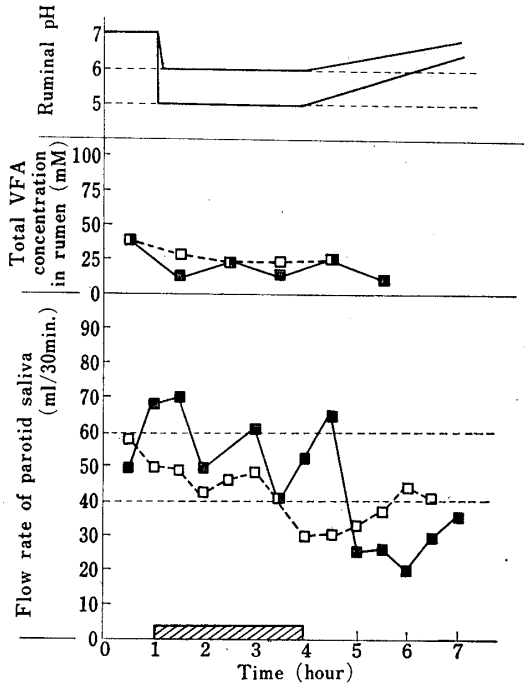

FIG. 3 Changes of the unilateral parotid salivary flow and the ruminal condition while the rumen pH was maintained at 6 (□) or 5 (■) for 3 hours (1–4 hour) by the administration of hydrochloric acid into the rumen.
The total amount of hydrochloric acid administrated into the rumen were 0.30 and 0.55 moles at pH 6 and pH 5, respectively.

fluid was the highest among the three VFA administrations. The saliva secretion rate remarkably decreased during the butyric acid infusion period. As the pH returned to its normal range, the flow rate was also restored to normal. The experimental animal developed such symptoms as somnolence, coughing and grinding the teeth. Urinary pH decreased from the control level (8.7) to 6.6 and ketone bodies concentration in the urine reached a maximam level at 2 hours after the butyric acid infusion was stopped. When the changes of urinary properties became obvious, however, the saliva secretion rate had already returned to the normal level.

Figure 3 shows the changes of the salivary flow when the ruminal pH was maintained at 6 or 5 by the addition of hydrochloric acid into the rumen. The total amount of HCl needed to reduce the ruminal pH to 5 or 6 and maintain these for three hours were 0.55 and 0.30 moles, respectively. The VFA level in ruminal fluid decreased by HCl infusion into the rumen. Hydrochloric acid administration did not affect the flow rate although some decrease was observed after recovery of the ruminal pH. This decrease of the flow rate was accompanied by the decline of urinary pH.

Discussion

The data presented here were the parotid saliva secretion rate changes during the period of rumen pH maintenance at the level of 5 or 6 for three hours by the administration of acetic, propionic, butyric or hydrochloric acids through the rumen fistula. As shown in Figure 4, the salivary flow showed a different response to each acid introduction. This was an interesting finding because acetic, propio-

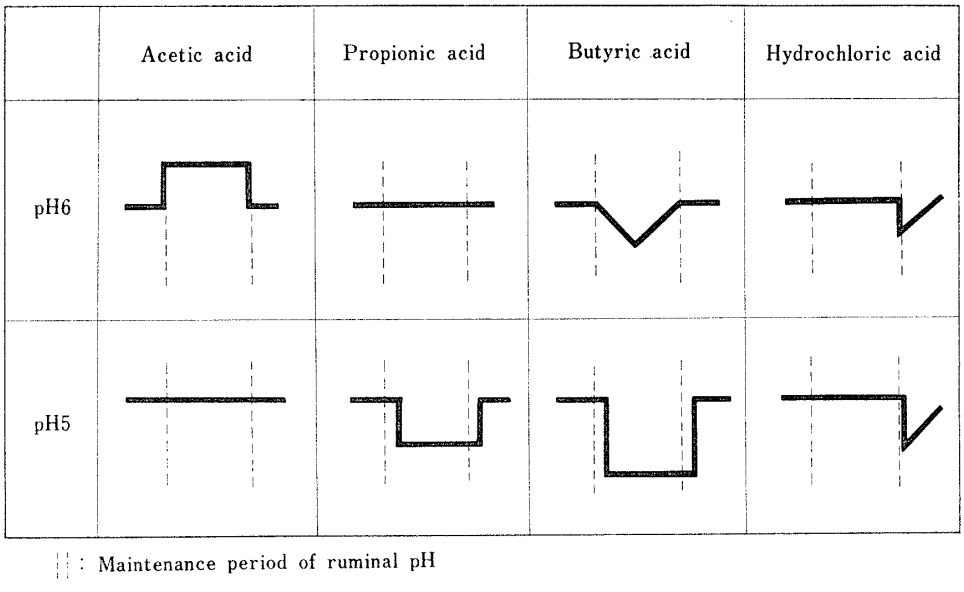

FIG. 4 Schematic drawing of changes of the unilateral parotid salivary flow while rumen pH were maintained at 5 and 6 by addition of VFAs and HCl to the rumen

nic or butyric acids are known to behave with their own particular metablic pattern in the body.

It is recognized that the absorption rate of VFA is higher on acidic side than the alkaline side of rumen fluid (6, 7). In this experiment, the difference of results between the pH 5 and 6 maintenance experiments may be due partly to the difference in the amount of absorbed acid.

Ash and Kay (1) reported that the introduction of fatty acid solutions into empty rumen caused a transient increase in the secretion of parotid saliva. They concluded that the VFA absorption accelerated the secretion of saliva. In the present experiment, the salivary flow increased up to 90 ml/30 min. while the ruminal pH was maintained at 6 by acetic acid infusion. This could be explained as the absorptive stimulation of the acetic acid because an increase of salivary secretion rate was observed immediately after the acid infusion. However, this increment was not observed in propionic or butyric acid administrations.

Pennington (8) reported that the presence of butyrate in the rumen led to a multiplication of the ketone bodies in the blood. In our experiment, the ketone bodies were excreted into the urine immediately after the butyrate administration into the rumen and they reached a maximum level at 4.5 hours after the administration. By that time, however, the saliva secretion rate has recovered to a normal level and the animal had already been restored from the somnolence. Menahan et al. (9) found that the urine ketone bodies fractions linearly and simultaneously correlate with their blood concentration. The difference in the secretion pattern of the saliva with that of the urine ketone bodies leads to the assumption that the blood ketone bodies may not be a main factor in depressing the saliva secretion rate. The role of the ketone bodies in saliva secretion, however, is a problem needing further investigation. Through the measurements of CO_2 content in the blood and pH of the urine, it is concluded that the acidosis developed by the acid infusion may contribute partly to the depression of the salivary flow, particularly in the case of hydrochloric acid infusion.

Another possibility considered to be a cause of inhibition in the parotid secretion is that the butyrate or propionate which were absorbed into the blood acting directly on the parotid gland to suppress its activity.

Ash (11) reported that fatty acid solution inhibits reticulo-rumen contraction by a peripheral stimulation of the acid sensitive receptors. The induced reduced rumen motility when the ruminal pH was maintained at 5 by the butyric or propionic acid administration could possibly account for the decrease of the saliva flow rate.

Hill (12), using the methylene blue perfusion technique, found free nerve endings in several areas of the reticulo-rumen. He postulated that these endings were probably the receptors of the reticulo-ruminal reflex. Considering both the experiments of Ash (11) and Hill (12) correlatively, it may be possible to imagine

that the chemoreceptors in the reticulo-rumen are the same as the nerve endings detected by Hill.

It seems likely that the VFA solution introduced into the rumen stimulates the chemorecepters and the excited receptors may have an influence on the activities of the salivary glands through the vagal afferent fibers. The extent of the influence may depend on the sort of VFA and the pH of the acid solution used. Since the hydrochloric acid did not affect the flow rate while the ruminal pH was maintained, it may not have acted on the chemoreceptors.

The difference of the results obtained between our present and previous investigations (5) seemed mainly depending on the acidity of the acid solution used, the property of the reticulo-rumen content and the method of administration to the rumen.

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