Effect of Hay to Concentrate Ratio on the Parotid Secretion and Its Sodium, Potassium and Phosphorus Levels in Sheep

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Abstract. High roughage diet (HRD) and high concentrate diet (HCD) were given to sheep to study their effects on the secretion rate of parotid saliva and on the sodium, potassium and phosphorus levels of parotid saliva and of blood.

Parotid secretion rate was higher in HRD feeding than in HCD feeding, except in the early period of eating. The start of eating caused an abrupt increase in parotid secretion. Secretion rate was lower in 2-hour post-eating period than in the 2-hour pre-eating period in both types of feeding.

The sodium level of parotid saliva was higher in HCD feeding than in HRD feeding, except in the early period of eating, though the daily intake of sodium was nearly the same in both types of feeding. Plasma sodium level was little influenced by the types of the diet, except in the post-eating period.

The potassium level of parotid saliva was little influenced by the type of diet in the pre-eating period. It was higher in HRD feeding than in HCD feeding in the eating period. Plasma potassium level was influenced neither by the type of diet nor by eating.

In response to the daily intake of phosphorus and the parotid secretion rate, the inorganic phosphorus level of parotid saliva and that of plasma were always higher in HCD feeding than in HRD feeding.

The hay to concentrate ratio affected the parotid secretion rate and its sodium and phosphorus levels, but not always influenced potassium level of parotid saliva.

In sheep, salivary secretion plays a very important role in the regulation of electrolyte metabolism. Renal-circulatory function and acid-base status are changed by eating. These changes are due to a rapid transfer of water and sodium from the blood to the digestive tract through the salivary gland [2, 16, 20].

It is well known that physical or chemical variation of diets has an effect on salivary secretion. There is, however, little information on the rate of salivary secretion and the changes of electrolyte concentration of the secreted saliva during eating.

It is well recognized that the parotid saliva of sheep is secreted continuously and occupies a large proportion in quantity of mixed saliva.

Scott [19] reported that changes in the ratio of roughage to concentrate of the diet caused some changes in phosphorus metabolism in sheep and calves, and sug-
gested that these changes might be related to the parotid function. It is expected that sodium and potassium levels of parotid saliva may be affected by the altered secretion rate of parotid saliva and by altered equilibration of extracellular fluid distribution during and after the eating period.

In the present experiment, the influence of the ratio of roughage (hay) to concentrate on the parotid secretion rate and the sodium, potassium and phosphorus levels in parotid saliva and in blood was investigated in the sheep.

Materials and Methods
1. Animals: Three sheep with an unilateral parotid fistula were used. They weighed 32-36 Kg, and were kept in wooden cages at an ambient temperature of 20±1°C.

2. Diets and water: The sheep were started on a high roughage diet feeding regimen (HRD feeding) in which 750 g of orchard grass hay and 150 g of formula feed were fed for 3 weeks. Then they were switched to a high concentrate diet feeding regimen (HCD feeding) in which 140 g of hay and 700 g of formula feed were fed for 6 weeks. Daily TDN intake was 550-560 g in both feeding regimens, and daily DCP intake was 80 g in HRD feeding and 110 g in HCD feeding [9]. The mineral contents of the diets are given in Table 1.

The animals were fed daily between 12:00 and 14:00. Feed intake was measured daily. It has been well established that the feeding of sodium bicarbonate is enough to compensate the loss of parotid saliva constituents from the body in the conventional feeding regimen [8]. Therefore, the animals were allowed to have a sodium bicarbonate solution (1.4%) ad libitum throughout the experimental period, except the sampling period (10:00-16:00). The consumption of this solution was measured daily.

3. Sample collection: About 1-2 hours before the sample collection, a saliva collection device was attached to the parotid fistula. The saliva was led into a graded cylinder via a polyethylene tube. A teflon tube was inserted into the jugular vein. The dead space (about 0.4 ml) of this cannula was filled with 3.5% sodium citrate solution to prevent the blood from clotting. One ml of blood was withdrawn immediately before blood collection to eliminate contaminated blood with the sodium citrate solution. Between 10:00 and 16:00, parotid saliva was collected every 10 minutes. The jugular blood (about 8 ml) was taken into a heparinized tube every 30 minutes. These samples were collected from each animal on two consecutive days in the last week of each feeding regimen.

4. Analytical method: Packed cell volume was determined by using microhematocrit capillary tube. Sodium, potassium and phosphorus levels in parotid saliva, plasma and diets were determined in the same manner as previously reported [17].

Results
1. Feed and water intake: In HRD feeding, one of the sheep employed refused to have a small amount of hay over a eating period of two hours. Its mean feed intake was 650 g of hay and 150 g of concentrate in the last week. The others left no residue of feed. The mean of eating time was 107(±3, S.E.) minutes in HRD feeding and 92(±9, S.E.) minutes in HCD feeding. The difference in it was not significant. The mean daily intake of sodium bicarbonate solution was 3.7(±0.2, S.E.) l

<table>
<thead>
<tr>
<th>Table 1. Mineral contents of the diet</th>
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<tbody>
<tr>
<td>Orchard grass hay</td>
</tr>
<tr>
<td>Passive**</td>
</tr>
<tr>
<td>0.22*</td>
</tr>
<tr>
<td>1.64</td>
</tr>
<tr>
<td>0.28</td>
</tr>
<tr>
<td>Concentrate**</td>
</tr>
<tr>
<td>0.33</td>
</tr>
<tr>
<td>0.83</td>
</tr>
<tr>
<td>0.53</td>
</tr>
</tbody>
</table>

*: % value on air dry basis.
**: Formula feed for dairy cattle (Nippon Formula Feed Mfg. Co.).

<table>
<thead>
<tr>
<th>Table 2. Mean intakes of sodium, potassium and phosphorus from the diets and NaHCO₃ solution (g/day)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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<tr>
<td>High roughage diet.</td>
</tr>
<tr>
<td>HCD</td>
</tr>
<tr>
<td>16.4 (14.3)</td>
</tr>
<tr>
<td>18.0 (15.4)</td>
</tr>
</tbody>
</table>

*: The figure in parentheses indicates Na intake as NaHCO₃.
**: Significantly different from the comparable value in the other type of feeding (P<0.01).
Table 3. Comparison of secretion rate of parotid saliva and its sodium, potassium and inorganic phosphorus levels in pre-eating, eating and post-eating period between the two types of feeding

<table>
<thead>
<tr>
<th></th>
<th>Diet</th>
<th>Pre-eating period</th>
<th>Eating period</th>
<th>Post-eating period</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>120 min</td>
<td>Early period</td>
<td>Late period</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>30 min</td>
<td>90 min</td>
</tr>
<tr>
<td>Secretion rate (ml/10 min)</td>
<td>HRD</td>
<td>21.7*** (0.8)</td>
<td>49.3 (3.0)</td>
<td>19.8*** (1.8)</td>
</tr>
<tr>
<td></td>
<td>HCD</td>
<td>9.9 (0.8)</td>
<td>46.8 (2.2)</td>
<td>7.7 (1.2)</td>
</tr>
<tr>
<td>Na (mEq/l)</td>
<td>HRD</td>
<td>161.0 (0.6)</td>
<td>160.0 (0.9)</td>
<td>163.6 (0.8)</td>
</tr>
<tr>
<td></td>
<td>HCD</td>
<td>167.9*** (0.7)</td>
<td>161.0 (0.4)</td>
<td>171.7*** (1.3)</td>
</tr>
<tr>
<td>K (mEq/l)</td>
<td>HRD</td>
<td>4.9 (0.1)</td>
<td>6.8* (0.1)</td>
<td>5.9*** (0.1)</td>
</tr>
<tr>
<td></td>
<td>HCD</td>
<td>5.0 (0.1)</td>
<td>6.3 (0.1)</td>
<td>5.3 (0.1)</td>
</tr>
<tr>
<td>Na/K ratio</td>
<td>HRD</td>
<td>33.2 (0.3)</td>
<td>23.9 (0.6)</td>
<td>28.5 (0.6)</td>
</tr>
<tr>
<td></td>
<td>HCD</td>
<td>34.0 (0.3)</td>
<td>25.9** (0.4)</td>
<td>32.7*** (0.5)</td>
</tr>
<tr>
<td>Inorganic P (mEq/l)</td>
<td>HRD</td>
<td>24.5 (0.9)</td>
<td>22.1 (0.8)</td>
<td>22.0 (0.6)</td>
</tr>
<tr>
<td></td>
<td>HCD</td>
<td>50.0*** (1.6)</td>
<td>27.7*** (1.3)</td>
<td>49.6*** (3.2)</td>
</tr>
</tbody>
</table>

HCD: High concentrate diet.
Each value is shown as mean ± (S.E.).
*, **, ***: Significantly different from the comparable value in feeding with the other diet at P<0.05(*), P<0.01(**) and P<0.001(***).

in HRD feeding and 4.0(±0.2, S.E.) l in HCD feeding. There was no significant difference in it between the two types of feeding. The daily intakes of sodium, potassium and phosphorus in both types of feeding are shown in Table 2. Daily intake of sodium did not differ significantly between the two types of feeding. In HRD feeding, however, potassium intake was higher and phosphorus intake lower than in HCD feeding.

2. Rate of unilateral secretion of parotid saliva and its sodium, potassium, and inorganic phosphorus levels: Fig. 1 shows the rate of unilateral secretion and the sodium, potassium and inorganic phosphorus levels of parotid saliva over a sampling period of 6 hours. Data obtained from the pre-eating, eating and post-eating periods expressed as the mean±S.E. are given in Table 3. Since the changes in these data for the first 30 minutes are quite different from those for the later 90 minutes of the eating period, the values estimated during the eating period are divided into two parts for explanation.

The secretion rate was significantly higher in HRD feeding than in HCD feeding throughout the experimental period, except the early stage of eating. In both types of feeding, eating caused a rapid increase in secretion rate, which was followed by a gradual decrease. This rate decreased to the same value as that in the pre-eating period at 50–60 minutes after the start of eating. In each type of feeding, the secretion rate was lower in the post-eating period than in the pre-eating period (P<0.001).

The sodium level of parotid saliva was always significantly lower (P<0.001) in HRD feeding than in HCD feeding, except
in the early stage of eating. It decreased significantly (P<0.001) from 167.9 (±0.7 S.E.) mEq/l in the pre-eating period to 161.0 (±0.4 S.E.) mEq/l in the first 30 minutes of the eating period in HCD feeding. In HRD feeding, however, the sodium level changes little due to the beginning of eating. At the mid-point (50–60 minutes) of the eating period, it began to increase progressively in each type of feeding.

In the pre-eating period, there was little difference in the potassium level of parotid saliva between the two regimens of feeding. The potassium level increased at the beginning of eating, and began to decrease 30–40 minutes after the start of eating. In HRD
Fig. 2. Changes in packed cell volume and plasma levels of sodium, potassium and inorganic phosphorus.

Feeding, the potassium level was significantly higher in the eating period and lower in the post-eating period than in HCD feeding.

The Na/K ratio of parotid saliva in the pre-eating period was not influenced by the type of feeding. In both types of feeding, it decreased for the first 30 minutes of the eating period significantly (P<0.001), and returned to its pre-eating value at 90–120 minutes after the start of eating.

The inorganic phosphorus level of parotid saliva was always higher in HCD feeding than in HRD feeding. It decreased in the former in the early stage of the eating period and increased progressively in the late stage of this period. In HRD feeding, however, it showed only a slight decrease in the eating period. In both types of feeding, it was higher in the post-eating period than in the pre-eating period (P<0.001).

3. Packed cell volume and plasma constituents (Fig. 2): There was no significant difference in packed cell volume between the two types of feeding. In both types of feeding, the average packed cell volume increased significantly (P<0.001) from 26.5 (±0.6 S.E.)% in the pre-eating period to 32.8 (±1.1 S.E.)% at 30 minutes after the start of eating, and returned to the pre-eating level in the post-eating period.

Plasma sodium level was not influenced by the diet in the pre-eating period. It increased progressively after eating. At the end of the eating period, it was 146.2 (±0.6 S.E.) mEq/l in average in both types of feeding, which was significantly (P<0.001) higher than 139.2 (±0.3 S.E.) mEq/l, the average of the pre-eating period. It was significantly higher (P<0.001) in HRD feeding (148.7±0.6 mEq/l) than in HCD feeding (145.9±0.5 mEq/l) at 3.5–4.0 hours after the start of eating. Plasma potassium level was influenced neither by the diet nor by the eating.

The mean plasma inorganic phosphorus level of 3.9 (±0.009 S.E.) mEq/l in HCD feeding throughout the sampling period was significantly higher (P<0.001) than that of 2.2 (±0.003 S.E.) mEq/l in HRD feeding. Eating caused a slight decrease in plasma inorganic phosphorus level transiently, but such decrease was not significantly different from the pre-eating value in both types of feeding.

Discussion

The secretion rate of parotid saliva was lower in HCD feeding than in HRD feeding, except in the early period of eating. Wheaton et al. [22] mentioned that the pH
of rumen fluid was lower in concentrate diet feeding than in roughage feeding in cattle. From the present experiment, it is suggested that the lower pH value and less physical stimulation in the rumen in HCD feeding than those in HRD feeding may lead to a lower secretion rate of parotid saliva. It was reported that the changes in physical form of the diet [10] and in ruminal pH [6, 13] had effects on parotid secretion.

In the early period of eating, no parotid secretion rate was influenced by the diet. In the present experiment, the daily ration was given within two hours. In this condition, it seemed that the sheep might have responded by secreting parotid saliva at a maximal rate at the beginning of eating. In HCD feeding, however, the secretion rate decreased faster than in HRD feeding. It may be due to the shorter eating time and the less stimulus to the receptors for salivation in the mouth in HCD feeding than in HRD feeding.

The decrease in secretion of parotid saliva in the later stage of eating and in the post-eating period might be mainly due to the increase in plasma osmolarity. The increase in plasma sodium level by eating might be the main cause of the increase in plasma osmolarity. Blair-West et al. [4] noticed a decrease in parotid secretion during the systemic infusion of hypertonic fluid. Satoh et al. [18] mentioned that the decrease in parotid secretion in the post-eating period was due to an increase in plasma osmolarity.

The sodium level of parotid saliva was higher in HCD feeding than in HRD feeding. This seems to concern the difference in sodium intake, though this difference was not significant (Table 2). It seems in sheep that sodium homeostasis may be controlled by the regulation of sodium secretion to the saliva and probably to the urine. No reason is known, however, why there was no difference in sodium level in the early period of eating between the two regimens of feeding. An abrupt increase in salivary potassium level by eating was seen in both types of feeding. It is difficult to explain the relationship between the start of eating and the increase in the potassium level of parotid saliva.

An increase in the flow of parotid saliva is associated with an increase in the sodium level and a decrease in the potassium level of the saliva [5]. In the present experiment, however, increase in parotid secretion rate in the early period of eating was not associated with the increase in sodium level or the decrease in potassium level.

Aldosterone causes a decrease in salivary Na/K ratio. The decrease in this ratio during the eating period in the present experiment seemed to have been brought about by the action of aldosterone. Sasaki [15] suggested that such decrease might be due to the increase of aldosterone secretion. It requires, however, a period of latency (for 70-120 minutes) for the parotid gland of sheep to respond to the administration of aldosterone [3]. Therefore, it has not been determined as yet whether the decrease in salivary Na/K ratio in the early eating period was attributed to aldosterone secretion or not.

In the present experiment, phosphorus intake was significantly higher in HCD feeding than in HRD feeding (Table 2). The plasma inorganic phosphorus level was higher in sheep fed a high phosphorus diet than in sheep fed a low phosphorus diet [14]. It has been reported, however, that the serum inorganic phosphorus level was higher in sheep fed a high concentrate diet than in sheep fed a roughage diet, although the two diets had almost the
same content of phosphorus [21]. Ligation of the parotid duct caused an increase in plasma inorganic phosphorus level in goat [17]. Therefore, it seems that the difference in plasma inorganic phosphorus level between the two types of feeding may be affected not only by the difference in dietary phosphorus intake but also by the salivary secretion rate.

Lawlor et al. [12] mentioned that differences in the inorganic phosphorus level of parotid saliva among sheep fed several kinds of diet depended on the level and availability of this element in each diet. It has been reported that the inorganic phosphorus level of parotid saliva is high at a slow secretion rate and low at a fast secretion rate in anesthetized goats [11] and conscious steers [1]. The difference in the inorganic phosphorus level of parotid saliva between the two types of feeding in the present experiment seems to be the reflection of the difference in the inorganic phosphorus level of blood and that in the parotid secretion rate.

The abrupt increase in the packed cell volume at the beginning of eating might be due to the remarkable water outflow from the blood to the rumen via the salivary gland. It might also be due to the red corpuscle inflow into the blood stream as a result of the splenic contraction [7].

References


