Effects of VFAs and Glucose Infusions on Ruminating Behavior of the Fasted-Goats

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ABSTRACT : To test their roles in rumination behavior, metabolites (acetic acid, propionic acid, butyric acid and glucose) were intravenously infused into the jugular vein of goats during fasting. The heads of four female goats tested were locked in a stanchion of cages in an experimental room. Ruminating behaviors with regard to number of ruminations, ruminating time, number of remastications and remasticating time were significantly decreased by acetic acid infusion ($p < 0.05$), and tended to be depressed more on values in butyric acid infusion or glucose infusion than those in pre-infusions, but propionic acid infusion decreased a little. Those data suggest that rumination receptors sensitive to VFAs and glucose are more likely to be situated in the area, where they would respond to blood levels.
(**Key Words**: VFAs, Glucose, Goats, Rumination, Intravenous Infusion)

INTRODUCTION

A ruminal role of rumination in reducing particle size of fibrous material is sufficiently to allow for its passage from the rumen (Kennedy, 1985; Pearce and Moir, 1964). The amount of time spent for rumination known as a part of ruminant digestion is influenced by a number of dietary conditions (Kick et al., 1937; Oltjen et al., 1962; Balch, 1952; Pearce, 1965). Ruminating behavior also influenced by feeding was reproted with goats (Bell and Lawn, 1957; Oshiro et al., 1988), with sheep (Gordon, 1958; Gordon and McAllister, 1970; Harumoto and Kato, 1979; Murphy et al., 1983) and with cattle (Suzuki et al., 1967). Some observations (Gordon and McAllister, 1970; Oshiro, 1985a; Oshiro, 1985b; Oshiro and Katayama, 1987; Oshiro and Koja, 1987; Oshiro et al., 1996b) have reported that the correlation between ruminating behavior and masticating behavior (or lighting) are important to determine rumination circadian rhythm during 24 hours.

It was reported that ruminants would adjust voluntary food intake in relation to physiological demand for energy (VFAs) (Bail, 1971; Bail and Mayer, 1968). The possible effect of acetate, propionate and butyrate intraruminal infusion on the mastication of ruminants was reported with sheep (Ulyatt, 1965) and with cattle (Simkins, 1967). But Forbes (1986) has reported that intravenous VFAs infusinos have no effects on the food intake of sheep. In a previous paper (Oshiro et al., 1992; Oshiro et al., 1996a), number of ruminations kept up or increased for a couple of days in the fasted-goats, but ruminating time (remasticating time per bolus) decreased from the second day after fasting (Oshiro et al., 1992) and VFAs decreased after fasting (Pothoven and Beitz, 1975). After feeding, acetic acid (volatile fatty acid) were increased in rumen and blood of steers (Pothoven and Beitz, 1975), and ruminating behavior decreased in goats after feeding (Oshiro, 1985a; Oshiro, 1985b; Oshiro and Katayama, 1987).

Those present studies were to determine the relationship between metabolites (VFAs and glucose) and ruminating behavior with the fed-goats and the fasted-goats under the continuously lit environment. In particular, the object of studies to be reported in this experiment is to investigate the effect of intravenous infusins of acetic acid, propionic acid, butyric acid and glucose on rumination behavior.

MATERIALS AND METHODS

Four goats Saanen crossbred (B. W.: means ± S. D.; 35.5 ± 2.3 kg) with a jugular vein cannula were fed with alfalfa hay cube (3 × 3× 1.7cm) under ad. libitum with water during 16 hours (17:00 through 09:00) in a day, and were fed nothing during other time (09:00 through 17:00). The head of each goat was locked in a stanchion of a 1.0 m height of metabolism cage in an experimental

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room, and room temperature and relative humidity were maintained at 22.0 ± 0.5℃ and 61 ± 3%, respectively and room was kept lit for 24 hours a day. The present experiments were conducted with the goats which had been already accustomed to restricted feeding from 17:00 through 09:00 of the next day for 4 weeks. Goats were put on a pick up (chewing sensor) of jaw movement and connected to an infusion apparatus from 09:00 till 09:15 because animals were catheterized intravenously into jugular vein and experimental apparatus was set at the previous day and all data were collected from 10:00 through 17:00. Non-infusion, saline, acetic acid, propionic acid, butyric acid and glucose were infused. The effects of non infusion (control), and intravenous infusions of saline, acetic acid, propionic acid, butyric acid and glucose on ruminating and masticating behaviors were investigated in the fasted-goats. The infusions were made into a jugular vein (toward the heart) via a peristaltic pump (MICRO TUBE PUMP: MP-3, TOKYO RIKAKIKAI CO., LTD.) through a polyethylene catheter. Saline, acetic acid, Propionic acid, butyric acid and glucose were infused during five hours from 12:00 through 17:00 in each experiment.

Acetic acid, propionic acid, butyric acid and glucose were infused by the rate of 0.05, 0.03, 0.01 mmoles/kg/min, and 1 mg/kg/min, respectively, and pH was adjusted to 7.0 with a solution of NaOH. All infusions were given at the rate of 0.01 ml/kg/min by a slow infusion apparatus (peristaltic pump). Each metabolites were treated to four goats with 3 weeks interval. Animals' jaw movement was recorded continuously from 10:00 through 17:00 on the auto-counter system (LB-8801, TECMO CO. LTD.) (Oshiro et al., 1987) by a pick up of jaw movement, and while these experiments were not conducted, animals were always put on temporarily pick up for the adaptation of jaw movement always. The results were analyzed into the following two components; ruminating (number of boli and ruminating time), and resting time. Ruminating was further analyzed into its constituent parts; number of remastications (chews/hour), remasticating time (min/hour), intermittent time (min/hour), bolus time (sec/bolus), number of remastications per bolus (chews/bolus), remasticating time per bolus (sec/blous) and intermittent time per bolus (sec/bolus) in each rumination and averages for all these within each hour of rumination and within each day. Food and water intakes were measured at 09:00 once a day in each experiment. Statistical analyses were conducted by analysis of variance and comparison among means by the method of Tukey as outlined by Snedecor and Cochran (1967).

RESULTS

The results of VFAs and glucose infusions in the jugular vein are shown in table 1.

Number of boli, ruminating time, number of remastications, remasticating time and intermittent time were significantly lower during infusion period than pre-infusion in acetic acid infusion experiment ($p < 0.05$), although resting time was significantly higher during acetic acid infusion than pre-infusion ($p < 0.05$). Number of boli, ruminating time, number of remastications, remasticating time and intermittent time tend to be lower during propionic acid, butyric acid and glucose infusion than in pre-infusion, although resting time tended to be longer by butyric acid infusion than pre-infusion. Among the treatments, ruminating behaviors were lower in acetic acid infusion than in non-infusion and saline-infusion.

Bolus time, number of remastications per bolus, remasticating time per bolus, and intermittent time per bolus were not different between pre-infusion and after-infusion periods in non-infusion, saline, acetic acid, propionic acid, butyric acid, and glucose infusions experiments.

Figure 1 shows a histogram per hour of ruminating time obtained from the data which was pooled in all four animals for three days.

There was significant decrease of ruminating time for an hour immediately after acetic acid infusion ($p < 0.05$), and kept up lower than pre-infusion. There was a lowest ruminating time at three hours after propionic acid infusion, and after that, ruminating time tended to increase. The lower value of ruminating time during butyric acid or glucose infusions were steady state, although it was lowest immediately after butyric acid infusion. A glucose infusion decreased ruminating time at two hours after the infusion, and kept up a lower value during infusion.

DISCUSSION

Food intake and water intake of goats per day were not different among non-injection, saline infusion, acetic acid infusion, propionic acid infusion, butyric acid, and glucose infusion for five hours infusion period from 12:00 through 17:00. The results in the present experiment did not recognize any effect of acetic acid, propionic acid and butyric acid infusion on food intake and water intake. It was also reported that food intake was not decreased by infusions during spontaneous meals of acetate into the jugular vein of goats (Bail and Mayer, 1968). However, this is not a strong evidence that VFAs concentrations in

Table 1. Ruminating behavior per hour and ruminating behavior per bolus in non-infusion, saline-, acetate-, propionate-, butyrate and glucose-infusion to goats

		Non-Inf**	Saline-Inf	Acetate-Inf	Prop-Inf	Butylate-Inf	Glucose-Inf
Number of boli							
boli/hour	P-I	23.5± 4.4	17.1± 4.6	21.6± 3.6*	19.3± 4.6	23.2± 4.3	19.5± 2.5
	A-I	20.7± 6.0	19.4± 5.0	9.4± 1.5	15.5± 4.1	16.6± 3.2	11.9± 2.7
Ruminating time							
min/hour	P-I	22.1± 4.7	15.7± 2.6	21.4± 1.9*	21.5± 7.0	22.0± 4.0	20.0± 2.7
	A-I	20.4± 4.6	18.4± 3.0	10.9± 1.9	18.1± 5.3	15.3± 2.7	11.3± 2.7
Number of remastication							
chews/hour	P-I	1,764±459	1,228±274	1,651± 68*	1,566±342	1,771±152	1,434±170
	A-I	1,588±339	1,519±170	860±186	1,391±398	1,183±223	808±228
Remasticating time							
min/hour	P-I	18.2± 3.6	13.2± 2.7	18.9± 1.8*	16.7± 6.4	19.1± 3.4	16.3± 2.3
	A-I	17.7± 3.8	17.1± 2.7	9.7± 1.8	15.0± 5.7	13.2± 2.3	9.3± 2.0
Intermittent time							
min/hour	P-I	3.8± 1.1	2.6± 0.1	2.5± 0.8*	2.8± 0.2	2.9± 0.7	3.7± 1.0
	A-I	2.7± 0.8	2.5± 0.9	1.2± 0.4	2.1± 0.4	2.1± 0.4	1.9± 1.7
Resting time							
min/hour	P-I	37.9± 4.7	43.3± 3.2	38.6± 1.9*	38.5± 7.0	38.0± 4.0	44.0± 2.7
	A-I	39.6± 4.6	49.4± 3.3	49.1± 1.9*	41.9± 5.3	44.7± 2.7	48.7± 2.2
Bolus time							
sec/bolus	P-I	56.3± 3.3	60.0± 5.7	60.0± 6.0	60.6± 5.7	57.0± 3.2	61.5± 3.9
	A-I	60.4± 6.0	62.5± 7.6	69.5± 4.9	67.0± 9.5	55.2± 0.8	55.6± 3.7
Remasticating							
time per bolus	P-I	46.7± 2.9	49.2± 1.9	53.2± 6.2	51.8± 6.9	48.8± 4.2	50.2± 2.8
sec/bolus	A-I	52.5± 5.4	54.8± 8.2	61.9± 4.8	58.5± 8.9	47.7± 0.8	47.1± 4.9
Intermittent							
time per bolus	P-I	9.6± 1.2	10.8± 3.7	6.8± 0.5	8.8± 1.5	7.5± 0.8	11.7± 1.2
sec/bolus	A-I	7.9± 1.0	7.7± 1.3	7.6± 0.8	8.4± 1.4	7.6± 0.4	9.0± 4.1
Number of							
remastication	P-I	74.6± 9.9	73.3± 7.6	78.3± 13.1	80.0± 16.0	77.9± 13.8	73.9± 4.8
chews/bolus	A-I	79.2± 14.4	81.4± 16.1	90.9± 8.8	88.3± 20.1	71.4± 5.9	67.2± 11.0

* : Means having the superscripts are significantly different in the same row ($p < 0.05$).
** : Infusion, P-I: Pre-Infusion, A-I: After-Infusion.

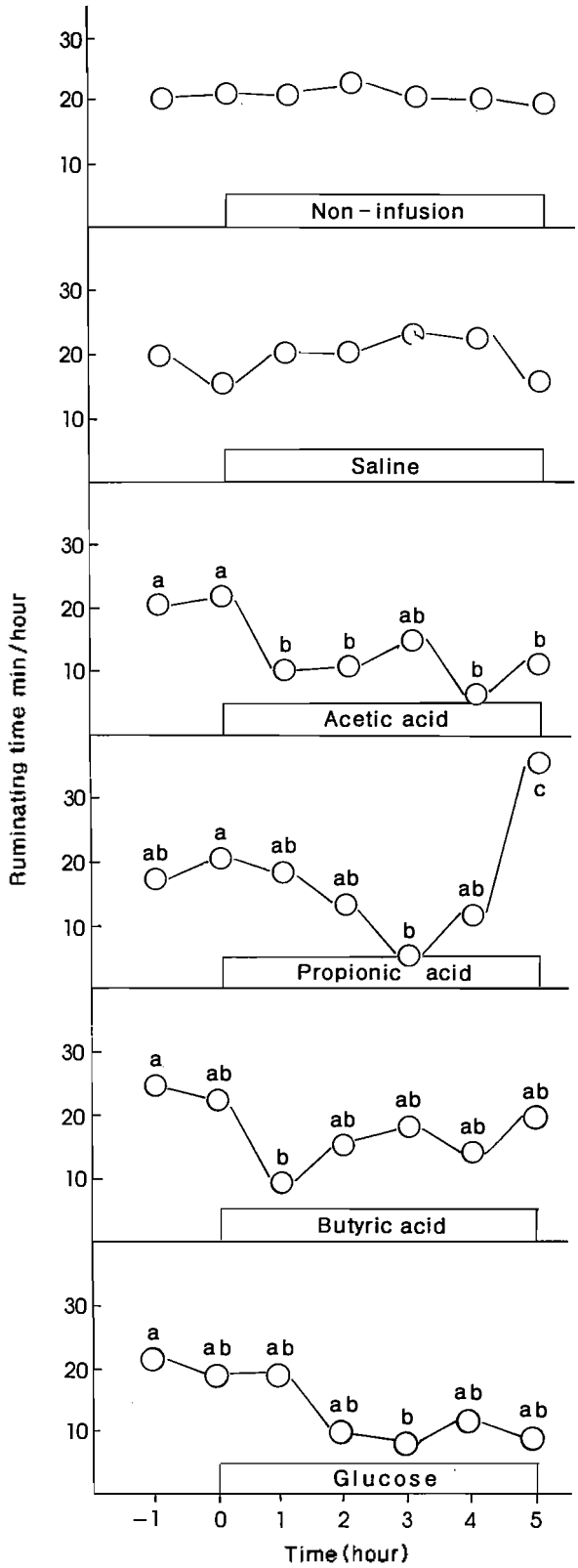

Figure 1. Changes of ruminating time by non-infusion, saline, acetic acid, propionic acid, butyric acid and glucose infusion.
a, b, c: means with a different letter are differ significantly ($p < 0.05$).

the jugular vein did not decrease food intake.

Several workers (Gordon and McAllister, 1970; Oshiro, 1985b; Oshiro and Katayama, 1987; Oshiro and Koja, 1987) have indicated that feeding has some effects of ths increase on mastication and the decrease on rumination at the same time. The results obtained with goats by author et al. (Oshiro et al., 1988; Oshiro and Katayama, 1987) shows that there are none or a decrease of ruminating behavior during and after feeding in continuous light.

Because the high concentrations of blood and rumen VFAs after feeding are reported with steers by Pothoven and Beitz (1975), it is considered that the decrease of ruminating behavior after feeding (Oshiro, 1985a,; Oshiro, 1985b) results from the increase of acetic acid in rumen and blood of ruminants.

During feeding, VFAs were increased in rumen and blood, and during fasting, VFAs were decreased in rumen and blood (Pothoven and Beitz, 1975). In the present experiment, an acetic acid infusion into jugular vein decreased rumination behavior, as mentioned above. It is suggested that the decreases of rumination behavior during and after feeding would be occurred by the increase of acetic acid resulted from feeding, and the increase of rumination behavior during fasting would be happened by the decrease of acetic acid resulted from fasting. Results of those experiments suggest that ruminants adjust ruminating behavior before adjusting voluntarily, although Montgomery and Baumgardt (1965) support the hypothesis that ruminants will adjust voluntary food intake in relation to physiological demand for energy if fill or rumen load does not limit their consumption.

In non-infusion and saline infusion, ruminating behavior kept up number of boli in the fasting as in the feeding in figure 1.

In the present experiments, acetic acid and butyric acid infusions depressed rumination behavior. Especially, acetic acid infusion decreased ruminating behavior significantly ($p < 0.05$). Propionic acid infusion tended to increase ruminating behavior, although it decreased temporarily at three hours after the infusion. Glucose infusion depressed the reduction of fatty acid, including acetic acid, in the rumen (Murray et al., 1990), and decreased production of Ketone body (acetone), and therefore, decreased ruminating behavior.

It suggested that the depression of rumination behavior after the feeding was occurred not only by the increase of mastication behavior immediately during the feeding but by the increasing blood acetic acid, butyric acid and glucose during and after the feeding. Those data suggest that rumination receptors sensitive to VFAs are

more likely to be situated in the area where they would respond to blood levels.

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