

Significance of Feeding Induced Hypovolemia in Feed Intake Control of Goats Fed on Alfalfa Hay

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ABSTRACT : The objective of this study was to examine whether feeding induced hypovolemia (decrease in plasma volume) acts on the regulation of feed intake in goats fed on dry forage. In order to prevent feeding induced hypovolemia, a 2 h intravenous infusion (16-18 ml/min) of isotonic mannitol solution was begun 1 h prior to feeding and continued until 1 h after the start of the 2 h feeding period. The intravenous infusion of isotonic mannitol solution (MI) decreased plasma osmolality by 1.0%, plasma total protein concentration by 4.2% and hematocrit by 5.9%, respectively. In comparison with no infusion (NI), MI significantly decreased thirst level by approximately 13%. At the completion of the 2 h feeding period, cumulative feed intake had been increased by 43% by MI. In conclusion, feeding induced hypovolemia in goats fed on dry forage increased thirst level more than the increase in plasma osmolality did. The results demonstrate that feeding induced hypovolemia is one of the factors controlling feed intake in goats fed on dry forage. (*Asian-Aust. J. Anim. Sci.* 2002, Vol 15, No. 3 : 366-370)

Key Words : Hypovolemia, Alfalfa Hay, Feed Intake Control, Thirst, Goat

INTRODUCTION

Mechanisms exist in ruminants to detect changes in the plasma osmolality and the plasma volume with feeding in order to maintain fluid and electrolyte homeostasis (Carter and Grovum, 1990). The importance of plasma volume as one of the factors affecting feed intake has not received much attention.

A recent experiment (Prasetyono et al., 2000) found that there was a significant positive regression ($R^2=0.99$) between plasma volume and cumulative feed intake. It was also reported that there was a negative correlation ($R^2=0.97$) between thirst level and cumulative feed intake in goats fed on dry feed. These findings suggested that there seems to be a complex feedback mechanism in thirst level, plasma volume and feed intake during the feeding of goats fed on dry feed.

Another experiment (Sunagawa et al., 2001b) suggested that decrease in plasma volume (hypovolemia) due to feeding plays a more important role in the regulation of feed intake of goats fed on dry feed than the loss of sodium from the circulating blood. In this experiment, the solutions used were hypotonic artificial saliva and mannitol solutions. In addition, both solutions infused had similarities in osmolality and volume. The feed intake of goats receiving either solution was significantly ($p<0.05$) increased when compared to that in the no infusion treatment. However, no differences in feed intake were found between both artificial

saliva infusion and mannitol infusion. It is not clear whether hypovolemia or hyperosmolality following feeding is effective on the regulation of feed intake in goats fed on dry feed. Based on that finding, it is hypothesized that hypovolemia plays an important role in the regulation of dry feed intake.

The isotonic mannitol used in the present study examines whether hypovolemia with feeding acts on the regulation of feed intake in goats fed on dry feed. In order to prevent feeding-induced hypovolemia, a 2 h intravenous infusion (16-18 ml/min) of isotonic mannitol solution was begun 1 h prior to feeding and continued until 1 h after the start of the 2 h feeding period.

MATERIALS AND METHODS

Animals

Five Japanese Saanen male goats, weighing 73 ± 10 kg, were maintained in individual metabolic cages in the laboratory under thermoneutral conditions ($24\pm 0.14^\circ\text{C}$ and $78.2\pm 0.25\%$ relative humidity). During the experiment, mean values of body temperature, respiration rate and heart rate were 39.1°C , 22 breaths/min and 68 beats/min, respectively. One day before the initiation of the experiment, polyethylene cannulae (Immamura Company, Japan) were inserted into the jugular veins on both sides of the goats. One was used for infusion, and the other was used for collecting blood samples.

Experimental procedures

All animals were provided with alfalfa hay cubes twice a day (10:30, 2.5 kg and 16:00, 1.0 kg) before and during the experiment. The alfalfa hay cubes (84.30% dry matter) contained, on a dry matter basis, 18.7% crude protein, 2.4%

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Received May 17, 2001; Accepted November 19, 2001

crude fat, 29.7% crude fiber, 39.7% NFE, 45.9% NDF and 36.6% ADF.

During the experiment, feed consumption was measured at intervals of 10 min for the duration of the 2 h feeding period (10:30 to 12:30). The animals were deprived of water during feeding in both treatments. Following the completion of feeding, 10 L of water was provided for a period of 30 min. Thirst level (g/30 min) in this experiment was defined as the water intake for 30 min upon completion of the 2 h feeding period.

Two treatments were performed in goats deprived of water for 22 h: (1) no infusion (NI), and (2) mannitol infusion (MI). The same treatment was applied to all goats with a time interval of approximately one week between treatments. This allowed for animal recovery and minimized the compounding effect of the previous treatment.

The isotonic mannitol solution (without sodium, 0.27 M) was prepared with pH 7.4. The infusion treatments commenced 1 h before feeding and continued for 2 h (9:30 to 11:30). During these 2 h, 16-18 ml/min of mannitol solution was infused into the jugular vein with a motor-driven pump (Cole-Parmer Instrument Co., PA-21A, Chicago).

Parameters measured in this study were cumulative feed intake, rate of eating, thirst level, plasma osmolality, plasma total protein concentration and hematocrit. The cumulative feed intake (g DM) and the rate of eating (g DM/30 min) were measured during the 2 h of feeding (10:30 to 12:30 h). The rates of eating were determined using a measuring scale to measure the weight of the feed. 2.5 kg of roughly crushed alfalfa hay cubes was placed in a feed box attached to a 6 kg measuring scale. The weight of the remaining feed was measured every 10 min for the duration of the 2 h feeding period. Thirst level (g/30 min) in this experiment was defined as the water intake for 30 min upon completion of feeding.

Blood samples (5 ml) were collected through the polyethylene cannula into heparinized tubes. The blood was sampled at 9:30, 10:30, 10:45, 11:00, 11:15, 11:30, 12:00, 12:30, 13:00 and 13:15. Blood plasma was obtained by centrifugation (16,260×g, 10 min, 4°C).

Biochemical analysis

Hematocrit was determined by a hematocrit reader (Tomy Seiko, Ltd., Japan). Plasma protein and osmolality were measured by a refractometer (Atago Co., Ltd., Japan) and by an Osmometer (Model OM-6010, Kyoto, Daiichi Kagaku, Japan), respectively.

Statistical analysis

A two-way analysis of variance (repeated measurement) and subsequent *t*-tests were used to compare those

treatments. For statistical analyses, GLM procedures (SAS, 1990) were adopted.

RESULTS

Figure 1 shows the effect of intravenous infusion of isotonic mannitol solution on cumulative feed intake and rate of eating at 30, 60, 90 and 120 mins after the commencement of feeding in goats fed on dry feed. Generally, the isotonic mannitol infusion (MI) increased the cumulative feed intake at all times tested after feeding was commenced. In comparison with NI, cumulative feed intake was increased approximately 43% by MI after completion of the 2 h feeding period. The rate of eating was also increased 22% by MI, 22% at 30 mins, 119% at 60 mins, 157% at 90 mins and 3% at 120 mins. After the first 30 mins of feeding, the rate of eating decreased sharply, and subsequently declined gradually in both treatments.

Figure 2 shows the thirst level in both NI and MI. In comparison with NI, mannitol infusion (MI) significantly ($p < 0.05$) decreased thirst level by approximately 13% in goats fed on dry feed.

Figure 3 shows the effect of mannitol infusion (MI) on plasma osmolality, plasma total protein concentration and hematocrit in the bloods sampled at 60 min before feeding

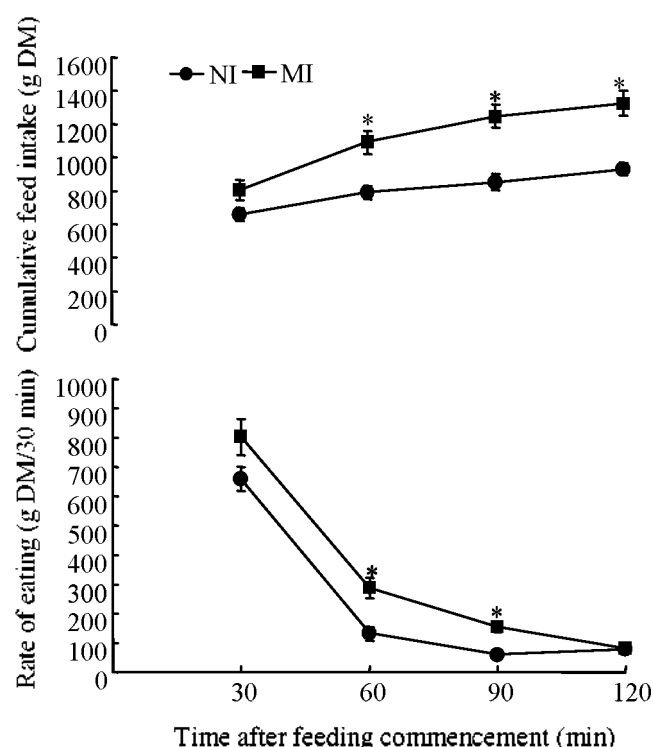


Figure 1. Average effect of intravenous infusion of isotonic mannitol solution (MI) on cumulative feed intake and rate of eating for 5 goats. Significant differences from the value in no infusion (NI) are indicated by * $p < 0.05$.

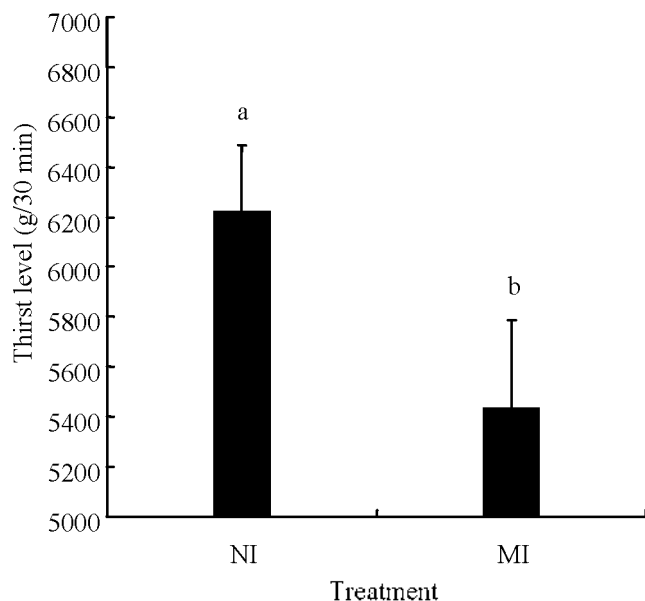


Figure 2. Average effect of intravenous infusion of isotonic mannitol solution (MI) on thirst level.

^{a,b} Means with different superscripts differ ($p < 0.05$).

and 0, 15, 30, 45, 60, 90, 120, 150 and 165 min after feeding was commenced. The mean concentrations of plasma osmolality, plasma total protein concentration and hematocrit prior to beginning the infusion and at 1 h after infusion of mannitol were 295.2, 293.0 mOsm/L; 7.0, 6.7 g/dl; 31.0, 29.2%, respectively. MI decreased plasma osmolality by 1.0%, plasma total protein concentration by 4.2% and hematocrit by 5.9%, respectively. There are no significant differences between NI and MI in plasma osmolality, plasma total protein concentration and hematocrit during feeding.

DISCUSSION

Sheep eating dry forage secrete large quantities of saliva (Denton, 1956; Stacy and Warner, 1966), which causes decreases in plasma volume. This activates the renin-angiotensin system, and results in the increase in arterial blood pressure, and the decrease in urine flow and sodium excretion during feeding (Blair-West and Brook, 1969; Sasaki et al., 1975). Changes in hematocrit and plasma total protein concentration reflected the changes in plasma volume (Blair-West and Brook, 1969). In sheep fed on alfalfa hay cubes, Otani et al. (1983) reported that the hematocrit value increased soon after feeding. Mathai et al. (1997) also reported that the plasma protein concentration in sheep fed on alfalfa dry chaff increased by 15% within 30 mins of feeding. Sato (1975) reported that circulating plasma volume estimated with Evans blue dye dilution method, decreased 10% during feeding in sheep fed alfalfa hay cubes. The Evans blue dye dilution method is to

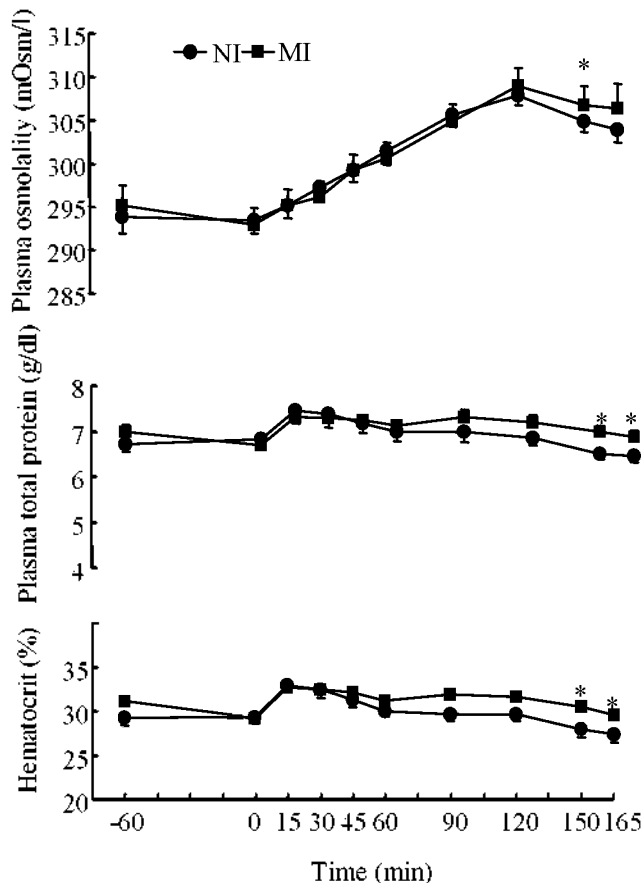


Figure 3. Average effect of intravenous infusion of isotonic mannitol solution (MI) on plasma osmolality, plasma total protein concentration and hematocrit for 5 goats. Significant differences from the value in no infusion (NI) are indicated by * $p < 0.05$.

calculate circulating plasma volume using the formula, amount of Evans blue injected into the jugular vein / plasma Evans blue concentration at the time of injection. In the no infusion (NI) treatment of the present experiment, before the goats started eating the hematocrit and plasma total protein concentration were 29.2%, 6.72 g/dl, and changed as follows after feeding: 15 min (32.9%, 7.44 g/dl), 30 min (32.4%, 7.38 g/dl), 45 min (31.3%, 7.18 g/dl), 60 min (30.0%, 7.00 g/dl). These results, therefore, indicate that the feeding itself in goats fed on alfalfa hay cubes induced hypovolemia during the first 1 h of the 2 h feeding period.

Hypovolemia was caused by fluid moving from the circulating blood into the saliva and gut soon after dry feed had been ingested. Within the second hour, hematocrit and plasma protein concentration returned to pre-feeding levels, but plasma osmolality continued to increase (figure 3). The increase of plasma osmolality appeared to depend on the continuous Na and Cl absorption from the rumen (Stacy and Warner, 1966; Warner and Stacy, 1972; Sunagawa et al., 2001a).

It was reported that feed intake of alfalfa pellets was regulated by changes in ruminal fluid osmolality (Baile et al., 1969; Kato et al., 1979; Grovum, 1995). The same sized dose of hyperosmotic NaCl, polyethylene glycol-400 (PEG), sodium acetate or sodium propionate produced increases in rumen fluid osmolality when intraruminally infused. These increases in rumen fluid osmolality resulted in the same sized decrease in feed intake (Grovum, 1995). On the other hand, when the rumen fluid osmolality was decreased by the intraruminal infusion of an excessive amount of warm water (39.8°C), feed intake increased markedly (Kato et al., 1979). It has been thought that the changes in rumen fluid osmolality were sensed by the osmoreceptors in the rumen wall and these signals were then transported into the central nervous system (Leek and Harding, 1975). However, the effect of internal humoral factors on the intake of dry feed has not been investigated under these experimental conditions.

In the present experiment, the prevention of decreases in extra cellular fluid volume (ECFV) with feeding through intravenous infusion of isotonic mannitol (MI) decreased hematocrit by 5.9% and plasma total protein concentration by 4.2% at 1 h after infusion (figure 3). In comparison with no infusion (NI), MI significantly decreased thirst level by approximately 13% in goats fed on dry feed (figure 2). A previous report (Prasetyono et al., 2000) indicated that the act of feeding itself induced thirst more than the length of water deprivation periods in water-deprived goats. From these results, it is thought that feeding induced hypovolemia in goats fed on dry forage produced thirst sensations in the brain.

A recent report (Prasetyono et al., 2000) found that plasma volume was involved in the decrease of feed intake in water-deprived goats. It was found that there was a significant positive regression between plasma volume and cumulative feed intake after completion of the 2 h feeding period. The present study indicates that MI significantly increases the cumulative feed intake as well as the rate of eating, compared to NI in goats fed on dry feed (figure 1). It is, therefore, thought that MI prevented increases in thirst levels produced by feeding-induced hypovolemia, and increased feed intake in goats fed on dry forage.

The change in plasma osmolality was less than the changes in both hematocrit and plasma protein concentration at 1 h after the infusion of the isotonic mannitol solution (figure 3). However, MI markedly decreased thirst levels in goats fed on dry feed (figure 2). This indicates that the changes in plasma volume with feeding play a more important role in the production of thirst sensations in the brain than the changes in plasma osmolality in goats fed on dry feed.

In conclusion, feeding induced hypovolemia in goats fed on dry forage increased thirst level more than the

increase in plasma osmolality did. The results demonstrate that feeding induced hypovolemia is one of the factors controlling feed intake in goats fed on dry forage.

ACKNOWLEDGMENTS

The authors wish to thank Mr. Sibata and Mr. Tezuka for helpful assistance in recording the data. We also thank Mr. G. McIlvride for help in preparing the manuscript.

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