Significance of Hypovolemia in Feed Intake Control of Goats Fed on Dry Feed

Katsunori Sunagawa*, Bambang W. H. E. Prasetiyono[1] and Akihisa Shinjo

Faculty of Agriculture, University of the Ryukyus, 1 Senbaru, Nishihara-cho, Okinawa 903-0213, Japan

ABSTRACT : The objective of this study was to examine the significance of feeding induced hypovolemia (decrease in plasma volume) in controlling the feed intake of goats fed on dry feed. In order to alleviate hypovolemia with feeding, a 2 h intravenous infusion (16-18 ml/min) of artificial saliva or mannitol solution was begun 1 h prior to feeding and continued until 1h after the start of the 2 h feeding period. In comparison with no infusion (NI), cumulative feed intake was increased by 41% with artificial saliva infusion (ASI) and by 45% with mannitol infusion (MI) by the completion of the 2 h feeding period. Both infusion treatments (ASI and MI) were significantly different ($p<0.05$) from the NI treatment in terms of the cumulative feed intake. The cumulative feed intake between the ASI and MI treatments was not significantly different ($p>0.05$). No infusion treatment (NI) had the lowest cumulative feed intake (929 g DM), whereas MI had the highest (1345 g DM), after completion of the 2 h feeding period. Generally, infusion treatments also increased the rate of eating at all time points after feeding was commenced. Following the first 30 mins of feeding, the rate of eating decreased sharply, and subsequently declined gradually in all treatments. Compared to the NI, both ASI and MI significantly ($p<0.05$) decreased thirst level (water intake for 30 mins after the completion of the 2 h feeding period) by approximately 13%. However, the thirst level caused by ASI and MI was not significantly different ($p>0.05$). Both ASI and MI decreased the plasma concentrations of osmolality and total protein, and hematocrit at 1 h after infusion. The results suggested that the thirst sensation in the brain could be produced by feeding induced hypovolemia. Moreover, the results indicate that hypovolemia is one of the factors controlling the feed intake of goats fed on dry feed. *(Asian-Aust. J. Anim. Sci. 2001. Vol 14, No. 9 : 1267-1271)*

Key Words : Hypovolemia, Dry Feed, Feed Intake, Thirst, Goat

INTRODUCTION

The availability of water is important during the feeding of ruminants fed on dry feed, such as alfalfa hay cubes (Prasetiyono et al., 2000). It is well known that there is a positive correlation between the amount of feed and water consumed in ruminants. Both feed and water consumption maintain homeostasis by replenishing or preventing deficits in metabolic fuels and fluids. Ruminants fed on dry feed secrete large quantities of saliva (Denton, 1956; Stacy and Warner, 1966), which causes severe demands on the sodium and water in the circulation. McKinley et al. (1994) reported that hypovolemia (decrease in plasma volume) in sheep occurred after dry feed had been ingested due to fluid moving from the circulation into the saliva. Thus, it is hypothesized that hypovolemia or sodium loss during feeding depresses the feed intake of ruminants fed on dry feed.

A decrease in plasma volume stimulates thirst in the brain (Guyton and Hall, 1996). A previous study of goats fed on dry feed, such as alfalfa hay cubes (Prasetiyono et al., 2000) found that an increase in thirst level quantitatively resulted in a decrease in feed intake. It was also suggested that a decrease in plasma volume might contribute to a decrease in feed intake of goats fed on dry feed. This study is designed to investigate what kinds of peripheral factors, especially plasma volume and plasma Na, act in the regulation of feed intake. Until now, how plasma volume and sodium contribute to the regulation of the feed intake of goats fed on dry feed has received little attention.

The objective of this study was to examine the significance of hypovolemia in controlling the feed intake of goats fed on dry feed. In order to alleviate hypovolemia with feeding, a 2 h intravenous infusion (16-18 ml/min) of artificial saliva or mannitol solution was begun 1 h prior to feeding and continued until 1h 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 (25±1°C and 86±9.5% relative humidity). During the experiment, the mean values of body temperature, respiration rate and heart rate were 39.0°C, 22 breaths/min and 66 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 each goat. 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

* Address reprint request to Katsunori Sunagawa. Tel: +81-98-895-8798, Fax: +81-98-895-8734. E-mail: b986094@agr.u-ryukyu.ac.jp.

[1] Faculty of Animal Sciences, Diponegoro University, Tembalang-Semarang, Central Java, Indonesia.

Received January 10, 2001; Accepted April 14, 2001

a day (10:30, 2.5 kg and 16:00 h, 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% crude fat, 29.7% crude fiber, 39.7% NFE, 45.9% NDF and 36.6 % ADF.

During the experiment, feed intake was measured at intervals of 10 min for the duration of the 2 h feeding period (10:30 to 12:30 h). The animals were deprived of water during feeding in all treatments. Following the completion of feeding, 10 L of water was provided for a period of 30 mins. 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.

Three treatments were performed in goats deprived of water for 22 h:(1) no infusion (NI), (2) artificial saliva infusion (ASI), and (3) mannitol infusion (MI). Repeated measurements were performed in this experiment. The same treatment was applied to all animals with a time interval of approximately one week between treatments. This allowed for animal recovery and minimized the compounding effect of the previous treatments.

The infusion treatments used in the present study were artificial saliva infusion (containing sodium) and mannitol infusion (without sodium, 0.22 M). The artificial saliva consisted of 115 mM $NaHCO_3$, 5 mM KCl and 30 mM $Na_2HPO_4.12H_2O$. Both the artificial saliva and mannitol solutions were prepared with pH 7.4 and 224 mOsmol/l.

The infusion treatments commenced 1 h before feeding and continued for 2 h (9:30 to 11:30 h). During these 2 h, 16-18 ml/min of artificial saliva or mannitol 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 protein and hematocrit. The cumulative feed intake (g DM) and the rate of eating (g DM/30 min) were measured during 2 hours 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 mins 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 mins upon completion of 2 hours 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, 5°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 Duncan's Multiple Range Tests were used to compare treatments. For statistical analyses, GLM procedures (SAS, 1990) were adopted.

RESULTS

Cumulative feed intake and rate of eating

Figure 1 shows the effect of infusion on cumulative feed intake and rate of eating at 30, 60, 90 and 120 mins after the commencement of feeding. Both artificial saliva (ASI) and mannitol (MI) infusion significantly ($p<0.05$) increased the cumulative feed intake after feeding was commenced.

Generally, infusion treatments also increased the rate of eating after feeding was commenced. After the first 30-mins of feeding, the rate of eating decreased sharply, and subsequently declined gradually in all treatments.

In comparison with NI, cumulative feed intake was increased by 41% wth ASI and by 45% with MI after completion of the 2 h feeding period. Both the infusion treatments (ASI and MI) were significantly different ($p<0.05$) from the NI in terms of the cumulative feed intake for all tests. The cumulative feed intake was not significantly different ($p>0.05$) between goats treated with ASI and those with MI treatment. No infusion treatment (NI) had the lowest cumulative feed intake (929 g DM), whereas MI had the highest (1345 g DM), after completion of the 2 h feeding period.

Thirst level

Infusion treatments significantly ($p<0.05$) decreased thirst level (figure 2). Compared to the NI, both ASI and MI decreased thirst level by approximately 13%. Both the ASI and the MI treatments were significantly different ($p<0.05$) from the NI treatment in their effects on thirst level. However, the thirst level caused by ASI and MI was not significantly different ($p>0.05$). Goats in NI had the highest thirst level (6220 g/30 min), whereas those in ASI had the lowest (5400 g/30 min).

Plasma osmolality

Figure 3 shows the effect of infusion on plasma osmolality in the blood sampled at 60 min before feeding and 0, 15, 30, 45, 60, 90, 120, 150, and 165 min after feeding was commenced. Both ASI and MI decreased plasma osmolality by approximately1 and 2%, respectively at 1 h after infusion. Similar conditions also occurred for 2 h

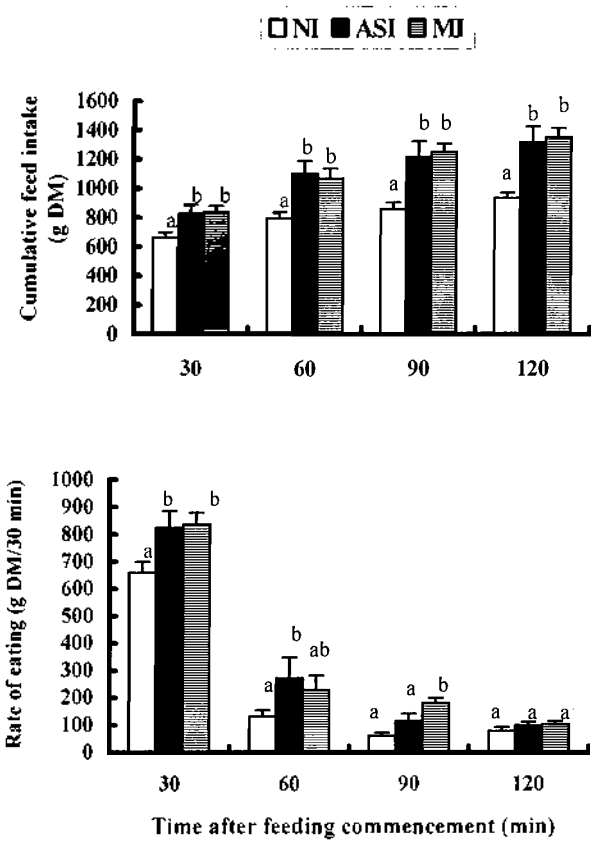

Figure 1. Average effect of infusion treatments on cumulative feed intake and rate of eating for 5 goats.
[a, b] Means with different superscripts differ ($p<0.05$).

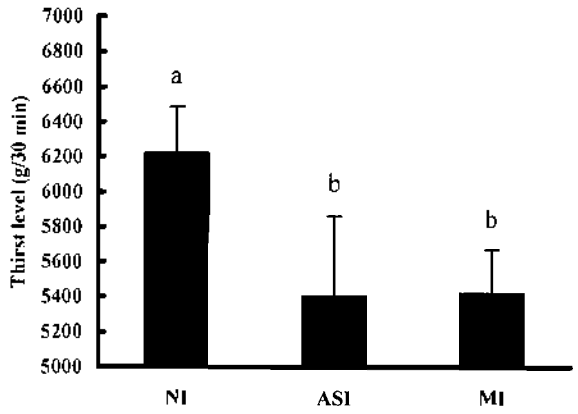

Figure 2. Average effect of infusion treatments on thirst level for 5 goats.
[a, b] Means with different superscripts differ ($p<0.05$).

after infusion treatments. However, the plasma osmolality caused by ASI vs MI was not significantly ($p>0.05$) different.

Plasma protein

Figure 3 shows the effect of infusion on plasma protein in the blood sampled at 60 mins before feeding and 0, 15, 30, 45, 60, 90, 120, 150, and 165 mins after feeding was commenced. Both ASI and MI decreased the plasma protein by approximately 6 and 3%, respectively at 1 h after infusion. However, the plasma protein caused by ASI vs MI was not significantly ($p>0.05$) different. The plasma protein also decreased after completion of the 2 h feeding period.

Hematocrit

Figure 3 shows the effect of infusion on hematocrit in the blood sampled at 60 mins before feeding and 0, 15, 30, 45, 60, 90, 120, 150, and 165 mins after feeding was commenced. Compared to the NI, both ASI and MI decreased hematocrit by approximately 8 and 5%, respectively at 1 h after infusion. The ASI significantly ($p<0.05$) decreased hematocrit, whereas the MI was not significantly different. The hematocrit caused by ASI vs MI was not significantly ($p>0.05$) different.

DISCUSSION

Several theories of feed intake regulation in ruminants have been developed as alternatives to the traditional view that feed consumption is limited by the physical and physiological constraints of the animal. Four peripheral factors known to depress feeding in ruminants are rumen fluid acetate concentration, rumen fluid propionate concentration, rumen fluid osmolality, and rumen distension (Bergen, 1972; Bailey and Forbes, 1974; Theurer and Wanderly, 1986). Other factors, such as hypovolemia, have not received much attention. A recent report (Prasetiyono 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 a 2 h feeding period. This study indicates that intravenous infusion of either artificial saliva or mannitol significantly ($p<0.05$) increases the cumulative feed intake as well as the rate of eating, compared to NI in goats fed on dry feed. This research suggested that hypovolemia is a controlling factor in dry feed intake. In agreement with other previous findings (Gutman and Krausz, 1969), hypovolemia can effectively suppress feeding.

The increase in the rate of eating is a reflection of the increase in feed intake in goats fed on dry feed, treated by either ASI or MI. Whereas, the rates of eating in goats fed on dry feed, treated without infusion were lower than those, treated by either ASI or MI. The decrease in rates of eating

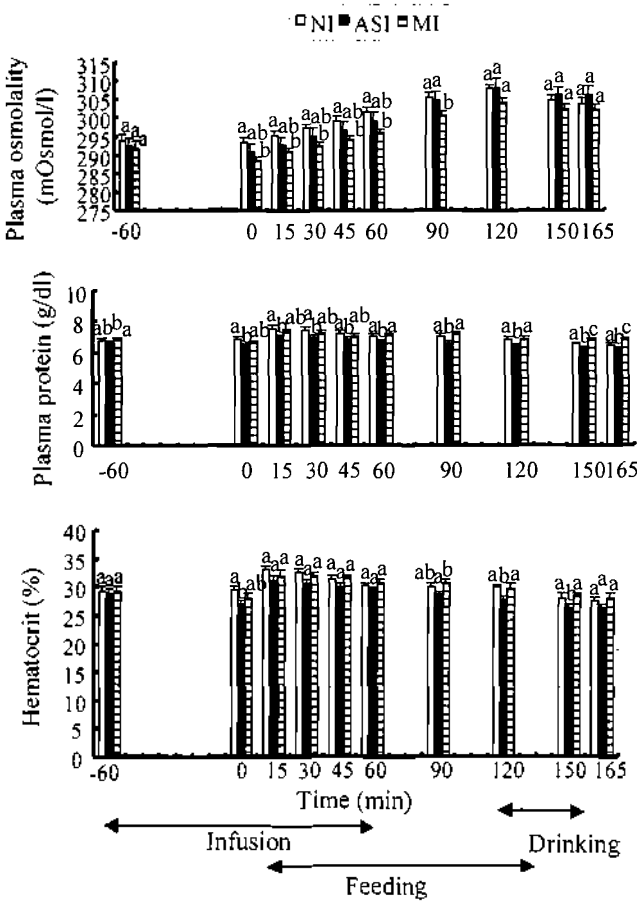

Figure 3. Average effect of infusion treatments on hematocrit, plasma protein and plasma osmolality for 5 goats. [a, b] Means with different superscripts differ ($p<0.05$).

in goats fed on dry feed was possibly due to a decrease in the salivary secretion rate (Prasetiyono et al., 2000). In a previous study on beef cattle fed on dry feed during water deprivation (Silanikove and Tadmor, 1989), reduction of feed intake and salivary secretion rates were linearly correlated ($p<0.01$). However, the regulating mechanisms controlling feed intake have not yet been examined in ruminants fed on dry feed. The rate of eating (figure 1) after the first 30 min of feeding decreased sharply and subsequently declined gradually in all of the treatments. These results support the previous findings of decreases in rates of eating after the first 30 mins of feeding in sheep (Forbes et al., 1972) and goats (Prasetiyono et al., 2000) fed on dry feed. Forbes et al. (1972) also reported that during the second and third 30 min periods there were progressive reductions in rates of eating.

In the present experiment, the alleviation of the decrease of extracellular fluid volume (ECFV) with feeding by intravenous infusion of either artificial saliva or mannitol significantly reduced thirst level by approximately 13% when water was offered for 30 min after the completion of the 2 h feeding period in goats fed on dry feed. This reduction in thirst level suggests that hypovolemia contributed to dehydration-induced thirst and feeding-induced thirst in goats fed on dry feed. A previous report (Prasetiyono et al., 2000) indicated that the act of feeding itself induced thirst more than the length of water-deprived periods in goats fed on dry feed. The present result was also supported by the decreases in plasma osmolality at 1 h after infusion (figure 3) resulted from either ASI or MI. Guyton and Hall (1996) stated that the increases in extracellular fluid osmolality cause intracellular dehydration in the thirst centers, thereby stimulating the sensation of thirst. In addition, the thirst level of goats with ASI and MI did not differ significantly ($p>0.05$), suggesting that hypovolemia stimulates thirst in goats fed on dry feed.

Both ASI and MI in the present study decreased plasma protein and hematocrit concentration (figure 3) at 1 h after infusion. These changes reflected that plasma volume increased by either ASI or MI in goats fed on dry feed. This agrees with the previous finding (Prasetiyono et al., 2000) that the changes of plasma protein concentration and hematocrit were simultaneous with the changes of plasma volume in goats fed on dry feed.

In conclusion, the results suggested that the thirst sensation in the brain could be produced by feeding induced hypovolemia. Moreover, the results indicate that hypovolemia is one of the controlling factors for feed intake in goats fed on dry feed.

ACKNOWLEDGMENTS

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

REFERENCES

Baile, C. A. and J. M. Forbes. 1974. Control of feed intake and regulation of energy balance in ruminants. Physiol. Rev. 54:160-214.

Bergen, W. G. 1972. Rumen osmolality as a factor in feed intake control of sheep. J. Anim. Sci.34:1054-1060.

Denton, D. A. 1956. The effect of Na^+ depletion on the Na^+ : K^+ ratio of the parotid saliva of the sheep. J. Physiol. 131:516-525.

Forbes, J. M., J. A. Wright and A. Bannister. 1972. A note on rate of eating in sheep. Animal Prod. 15:211-214.

Gutman, Y. and M. Krausz. 1969. Regulation of food intake and water intake in rats as related to plasma osmolality and volume. Physiol. Behav. 4:311-313.

Guyton, A. C. and J. E. Hall. 1996. Textbook of medical physiology. 9th Ed. W.B. Saunders Company, pp. 362.

McKinley, M. J., R. B. Harvey and L. Vivas. 1994. Reducing brain sodium concentration prevents post-prandial and dehydration-induced natriuresis in sheep. Acta Physiol Scand. 151:467-476.

Prasetiyono, B. W. H. E., K. Sunagawa, A. Shinjo and S. Shiroma. 2000. Physiological relationship between thirst level and feed intake in goats fed on alfalfa hay cubes. Asian-Aus. J. Anim. Sci. 13:1536-1541.

SAS. 1990. SAS/STAT User's Guide. Volume 2, Version 6, Fourth Edition. SAS Institute Inc., SAS Campus Drive, Cary, NC 27513.

Silanikove, N. and A. Tadmor. 1989. Rumen volume, saliva flow rate and systemic fluid homeostasis in dehydrated cattle. Am. J. Physiol. 256:R809-R815.

Stacy, B. D. and Warner, A. C. I. 1966. Balances of water and sodium in the rumen during feeding: osmotic stimulation of sodium absorption in the sheep. Jl. Exp. Physiol. 51:79-93.

Theurer, C. B. and R. C. Wanderly. 1986. Role of absorbed nutrients in feed intake control. In: F. Owens, D. Gill and K. Lusby (Ed.). Feed intake by beef cattle. Oklahoma State Univ. Rec. Rep. M.P. 121:275.