Physiological Relationship Between Thirst Level and Feed Intake in Goats Fed on Alfalfa Hay Cubes

Bambang W. H. E. Prasetiyono[1], Katsunori Sunagawa*, Akihisa Shinjo and Sadao Shiroma
Faculty of Agriculture, University of the Ryukyus, 1 Senbaru, Nishihara-cho, Okinawa 903-0213, Japan

ABSTRACT : The present study was carried out to measure changes of feed intake and thirst level caused by water deprivation in goats fed on dry feed and to elucidate the relationship between those two parameters. Water deprivation significantly ($p<0.01$) decreased cumulative feed intake and rate of eating at 30, 60, 90 and 120 min, respectively, after feed presentation. Cumulative feed intake, after completion of 2 h feeding, was reduced by about 20, 21 and 64 % due to water deprivation during feeding for 2 h (WD2), for 22 h (WD22) and for 46 h (WD46), respectively, compared to free access to water (FAW). Compared to the FAW, WD2, WD22 and WD46 increased thirst level by about 5, 5 and 9 times, respectively. Mean thirst level (X, g/30 min) was negatively correlated with cumulative feed intake (Y, g DM) after completion of 2h feeding ($Y=1302-0.2$ X, $r^2=0.97$, $p<0.05$). Water deprivation depressed plasma volume and there was a significant positive regression between plasma volume (X, ml) and cumulative feed intake (Y, g DM) after completion of 2h feeding ($Y=-1003+0.6$ X, $r^2=0.99$, $p<0.01$). Mean plasma osmolality (X, mOsmol/l) correlated significantly and negatively with cumulative feed intake (Y, g DM) after completion of 2h feeding ($Y=27004-84.9$ X, $r^2=0.95$, $p<0.05$). In conclusion, a decrease of feed intake during water deprivation is mainly due to an increase of thirst level quantitatively, and the act of feeding itself induces thirst more than the length of water-deprivation periods in goats fed on dry feeds. The present findings suggest that plasma osmolality and plasma volume which affect thirst level are involved in the decrease of feed intake in water-deprived goats. *(Asian-Aus. J. Anim. Sci. 2000. Vol. 13, No. 11 : 1536-1541)*

Key Words : Dry Feed, Feed Intake, Water Deprivation, Thirst, Goat, Plasma Changes

INTRODUCTION

Feed and water intake have been shown to be interdependent (Gutman and Krausz, 1969). Feed intake is a major determinant of fluid intake, and fluid intake appears to facilitate eating. On the other hand, feed intake is usually reduced when water is in short supply (Langhans et al., 1995).

Ruminants differ from monogastric animals because they have a large fluid reserve in the rumen, and because much more saliva is secreted during eating (Bailey, 1961). In many areas of the world, ruminants routinely have to cope with periods of dehydration (Langhans et al., 1995). It is also well known that ruminants are resistant to water deprivation.

The relationship between water and feed intake is influenced by several variables such as the composition of the feed, ambient temperature, and productive demands (Langhans et al., 1995). It was pointed out by Murphy (1992) that dry matter content of the diet has often been linked to water consumption of ruminants. In some countries of the world, such as Japan, ruminants are frequently offered with dry feed including hay, hay cubes and pellet to rise productivity. Therefore, it is interesting to know the importance of availability of water during feeding of ruminants fed on dry feeds.

Thirst (and water intake) in rats can be induced by various mechanisms, both by increased plasma osmolality through a hypertonic challenge (Fitzsimons, 1963) and by hypovolemia (Fitzsimons, 1961 and Oatley, 1964). Gutman and Krausz (1969) have reported that feed intake in rats as well as water intake depend to some extent on plasma osmolality.

The physiological mechanism that links feed intake and thirst has not received much attention. So far as we know, until now only scanty and not systemic work has been conducted to quantify the relationship between thirst level and feed intake.

The present study was carried out to measure changes of feed intake and thirst level caused by water deprivation in goats and to elucidate the relationship between those two parameters.

MATERIALS AND METHODS

Animals

Four male goats of Japan Saanen breed, weighing 44±1.0 kg, were tethered in individual pens and maintained in the laboratory under thermoneutral conditions (25±0.16℃ and 84.5±1.4% relative humidity). During the experiment, the mean values of body temperature, respiration rate and heart rate were 39.1℃, 22 breaths/min and 71 beats/min, respectively. One day before initiation of the experiment, a polyethylene cannula (Imamura Company, Japan) was

* 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.
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inserted into a jugular vein.

Experimental procedures

All animals were provided with alfalfa hay cubes once a day (10:00 h) 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 consumption was measured at intervals of 10 min for 2 hours (10:00 to 12:00 h). Water was provided in a bucket.

Four treatments were performed: (1) free access to water (FAW) (this treatment was a control in which water was freely available), (2) water deprivation during feeding for 2 hours (WD2), (3) water deprivation for 22 hours (WD22), and (4) water deprivation for 46 hours (WD46). Repeated measurements were performed in this experiment, in which the same treatment was applied repeatedly to all animals with a time interval of about one week between repetitions. The same length of time was allowed before the application of subsequent treatment to allow animal recovery and to minimize the confounding effect of previous treatments.

Parameters measured in this study were cumulative feed intake, rate of eating, thirst level, plasma volume, plasma osmolality, plasma protein and hematocrit. Cumulative feed intake (g DM) and rate of eating (g DM/30 min) were measured for 2 hours (10:00 to 12:00 h). Thirst level (g/30 min) in this experiment was defined as water intake for 30 min after completion of 2 hours feeding.

Blood samples were collected through the polyethylene cannula into heparinized tubes. The blood was sampled at 09:30, 10:00, 10:15, 10:30, 10:45, 11:00, 11:30, 12:00, 12:30 and 12:45 h. Blood plasma was obtained by centrifugation (Himac centrifuge, Hitachi) at 5℃ and 12,000 rpm within 10 min.

Analysis

Hematocrit was determined in Hematocrit reader (Tomy Seiko Co., Ltd., Japan). Plasma protein and plasma volume were measured refractrometrically (Atago Co., Ltd., Japan) and spectrophotometrically (Hitachi, Model 100-10, Japan), respectively. Plasma osmolality was determined in an Osmometer (Model OM-6010, Kyoto, Daiichi Kagaku, Japan).

Statistical analysis

Data of plasma volume, plasma osmolality, plasma protein and hematocrit from the blood samples collected at 12:00 h were used in this study.

A two-way analysis of variance (repeated measurements from four animals) and subsequent Duncan's Multiple Range Tests were used to compare those treatments. To analyze the relationships between two parameters, regression analysis was used. For statistical analysis, GLM procedure (SAS, 1990) were adopted. Data are presented as means ± SE.

RESULTS

Cumulative feed intake and rate of eating

Figure 1 shows the effect of water deprivation on cumulative feed intake at 30, 60, 90 and 120 min, respectively, after feed presentation. Water deprivation significantly ($p<0.01$) decreased the cumulative feed intake at all time points after feed presentation.

Water deprivation significantly ($p<0.01$) decreased rate of eating at 30, 60, 90 and 120 min, respectively, after feed presentation (figure 1). After the first 30 min of feed presentation, the rate of eating decreased sharply, and afterward gradually declined in all treatments.

Cumulative feed intake was reduced by about 20, 21 and 64% in WD2, WD22 and WD46, respectively, compared to the FAW, after completion of 2 h feeding (table 1). All of the water deprivation

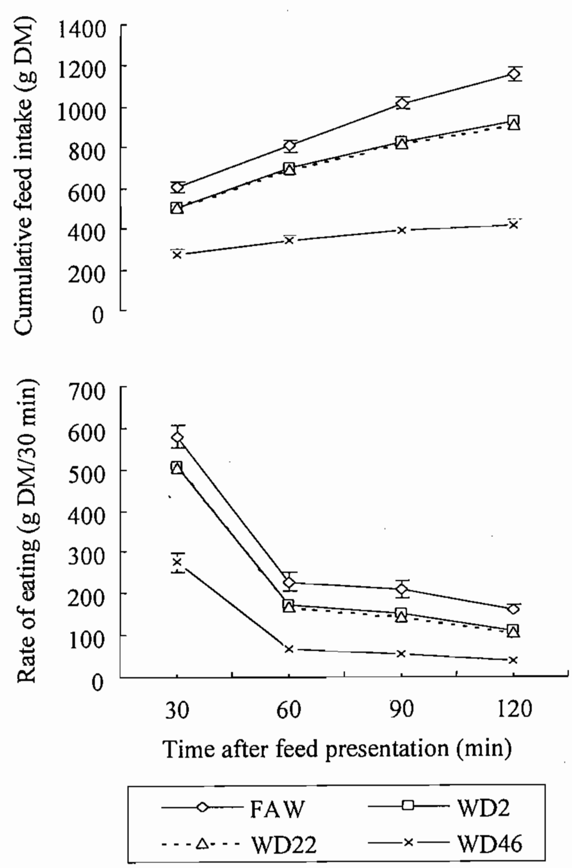

Figure 1. Effects of water deprivation on cumulative feed intake and rate of eating in goats. Each point is average of 11 number of observations.

treatments (WD2, WD22 and WD46) were significantly different ($p<0.01$) compared to the FAW for the cumulative feed intake. The cumulative feed intake caused by FAW vs WD2 and WD22 vs WD46 were significantly different ($p<0.01$). However, the cumulative feed intake caused by WD2 vs WD22 was not significantly different ($p>0.05$). Water deprivation WD46 had the lowest cumulative feed intake (422 g DM), whereas FAW had the highest (1160 g DM).

Thirst level

Water deprivation significantly ($p<0.01$) increased thirst level (table 1). Compared to the FAW, WD2, WD22 and WD46 increased thirst level by about 5, 5 and 9 times, respectively. All of the water deprivation treatments were significantly different ($p<0.01$) from the FAW on the thirst level. The thirst level caused by FAW vs WD2 and WD22 vs WD46 had significant differences ($p<0.01$). However, the thirst level caused by WD2 vs WD22 was not significantly different ($p>0.05$). FAW had the lowest thirst level (600 g / 30 min), whereas WD46 had the highest (5645 g / 30 min).

Mean thirst level (X, g/30 min) was negatively correlated with cumulative feed intake (Y, g DM) after completion of 2h feeding (figure 2).

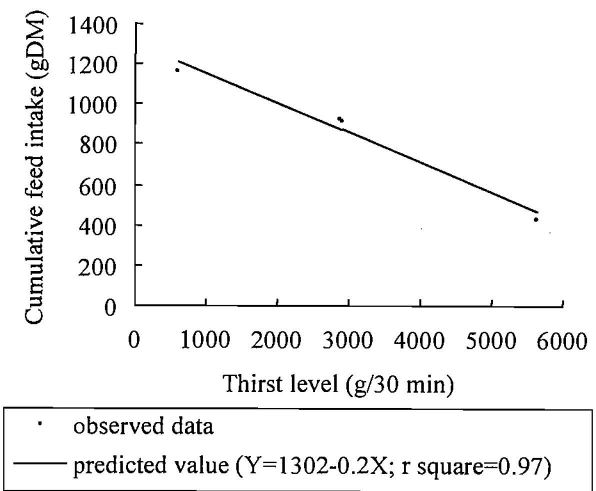

Figure 2. Relationship between thirst level and cumulative feed intake after completion of 2 hours feeding

Plasma volume

There was a significant effect ($p<0.05$) of water deprivation on plasma volume after completion of 2 h feeding (table 1). As shown in table 1, all of the water deprivation treatments were significantly different ($p<0.05$) from FAW for the plasma volume. The plasma volume of animals subjected to FAW and WD2 and also WD22 and WD46 differed significantly ($p<0.05$), whereas there was not a significant difference found between WD2 and WD22. The lowest plasma volume (2374 ml) was recorded on WD46, while highest (3598 ml) on the FAW treatment.

Water deprivation decreased plasma volume and there was a significant positive regression between plasma volume (X, ml) and cumulative feed intake (Y, g DM) after completion of 2 h feeding (figure 3).

Plasma osmolality

Water deprivation significantly ($p<0.05$) increased plasma osmolality. The highest plasma osmolality was attained by WD46 (313 mOsmol/l), while the lowest (305 mOsmol/l) was by FAW after completion of 2 h feeding (table 1). The plasma osmolality caused by FAW, WD2 and WD22 were not significantly different ($p>0.05$) from each other, however, FAW vs WD46 different significantly ($p<0.05$).

Mean plasma osmolality (X, mOsmol/l) correlated significantly and negatively with cumulative feed intake (Y, g DM) after completion of 2h feeding (figure 4).

Table 1. Mean values of cumulative feed intake, thirst level, plasma volume, plasma osmolality, plasma protein and hematocrit after completion of 2 hours feeding.

Parameters	Treatment				SEM	Significance
	FAW	WD2	WD22	WD46		
Cumulative feed intake (g DM)	1,160^{a}	928^{b}	915^{b}	422^{c}	38.23	$p<0.01$
Thirst level (g/30min)	600^{a}	2891^{b}	2,918^{b}	5,645^{c}	313.88	$p<0.01$
Plasma volume (ml)	3,598^{a}	3,110^{b}	3,196^{b}	2,374^{c}	85.10	$p<0.05$
Plasma osmolality (mOsmol/l)	305^{a}	306^{ab}	308^{ab}	313^{b}	1.97	$p<0.05$
Plasma protein (g/dl)	6.4^{a}	6.5^{a}	6.5^{a}	7.1^{b}	0.11	$p<0.05$
Hematocrit (%)	32.0^{a}	32.2^{a}	32.3^{a}	34.6^{b}	0.46	$p<0.05$

[a,b] Values having same letters in the same row are not significantly different ($p>0.05$).

FAW, WD2, WD22 and WD46 are free access to water, water deprivation during feeding for 2 h, water deprivation for 22 h and water deprivation for 46 h, respectively.

Plasma protein

There was a significant effect ($p<0.05$) of water deprivation on plasma protein (g/dl) (table 1). However, no significant differences ($p>0.05$) were found on these values among FAW, WD2 and WD22. Comparison of plasma protein concentration on various treatments indicated that WD46 had significantly highest plasma protein (7.1 g/dl).

Hematocrit

Water deprivation increased hematocrit concentration significantly ($p<0.05$) (table 1). The hematocrit concentrations caused by FAW, WD2 and WD22 were not significantly different ($p>0.05$) from each other, but these concentrations were different from WD46. FAW showed the lowest hematocrit value (32.0%), while WD46 showed the highest (34.6%).

DISCUSSION

The type of feed affects the rate of eating since dry feed is eaten more slowly than the same feed given in wet form. In the present study, the goats were given a dry feed, i.e. alfalfa hay cubes. According to Clough (1972) (cited by Forbes, 1995), cows ate pellets at 455 g min^{-1} and slurry at 1670 g min^{-1} and even though the slurry contained water, the rate of DM intake was considerably higher with the feed in this form.

In the present study, the rate of eating decreased significantly ($p<0.01$) in water-deprived goats (figure 1), which was possibly due to decrease in the saliva secretion rate. Generally, the decrease in the rate of eating reflects the decrease of feed intake. A previous study of beef cattle fed on dry feeds during water deprivation (Silanikove and Tadmor, 1989), reductions of feed intake and salivary secretion rates were linearly and significantly ($p<0.01$) correlated. However, the regulatory mechanisms of 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 feed presentation decreased sharply and gradually afterward, in all the treatments. This result supports the previous findings reported by Forbes et al. (1972) that rates of eating decreased after the first 30-min of feed presentation in sheep fed on dry feeds. It was also reported that during the second and third 30-min periods there were progressive reductions in rate of eating.

The goats used in this investigation were kept in a thermoneutral condition. This environmental condition was different from the environmental condition used by Silanikove and Tadmor (1989), in which the cattle were exposed to the hot environment. A previous report on goats (Silanikove, 1985) indicated that the reduction in feed intake in response to water deprivation was less in desert-ruminant breeds compared with non-desert breeds. Therefore, it seems likely that the reduction in feed intake in response to water deprivation is affected by environmental conditions and the breeds of the animal. As pointed out by Phillips (1961) (cited by Silanikove, 1985), reduction in feed intake as a consequence of limited water supply differs in tropical breeds of cattle (*Bos indicus*) and temperate zone breeds (*Bos taurus*), in which the former are able to eat (voluntarily) more feed under the same condition.

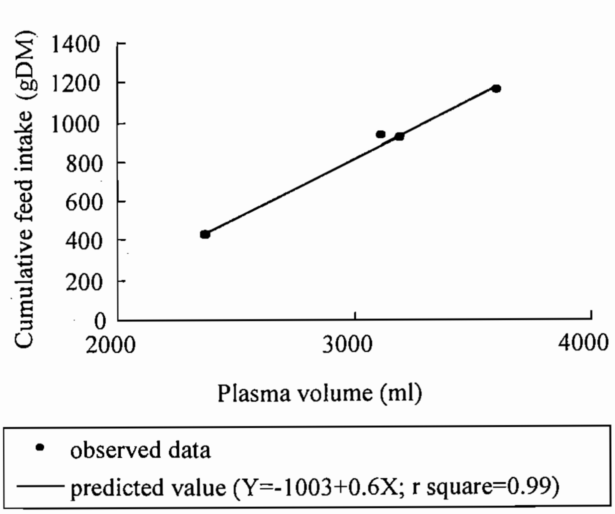

Figure 3. Relationship between plasma volume and cumulative feed intake after completion of 2 hours feeding

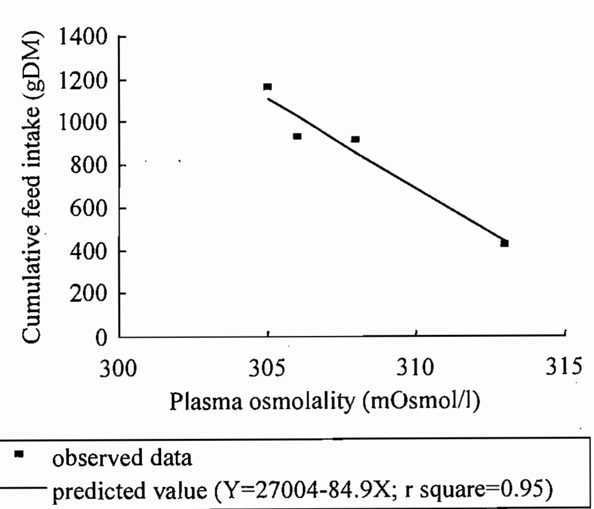

Figure 4. Relationship between plasma osmolality and cumulative feed intake after completion of 2 hours feeding

In the present experiment, the amount of water consumed by water-deprived goats was reflected in their thirst levels and the thirst levels increased quantitatively as a consequence of water deprivation (table 1). Meanwhile, the cumulative feed intake was linearly and negatively correlated to the increase in the thirst level (figure 2). Based on the regression equation in the figure 2, it could be estimated that there was a decrease of 0.2 g DM per 1 g/30 min thirst level in the cumulative feed intake.

There is an interesting result in the present experiment that the cumulative feed intake was significantly ($p<0.01$) decreased in WD2 compared to FAW (table 1). This result suggests that the availability of water is important during feeding in goats fed on dry feeds. The cumulative feed intake in WD2 and WD22 did not differ significantly ($p>0.05$), which may be due to similar thirst levels in these groups. Although the lengths of the water-deprivation period were different in both treatments, the similarities in effects on the thirst level of both WD2 and WD22 might indicate that the act of feeding itself induces thirst more than the length of water-deprivation periods.

Thirst is an appetitive mechanism under hypothalamus control (Ganong, 1997). It may be elicited by the stimulation of neurons which are located in the vicinity of the third ventricle (Anderson et al., 1969), and the area along the anteroventral wall of the third ventricle that stimulates thirst is the thirst center (Guyton and Hall, 1996). Furthermore, Park et al. (1986) and Guyton and Hall (1996) stated that increases in extracellular fluid osmolality and decreases in extracellular fluid volume stimulate thirst. These reports support finding of the present study that plasma osmolality increases in water-deprived goats, while plasma volume decreases. This increase of plasma osmolality and decrease of plasma volume reflects an increasing thirst level in response to water deprivation (table 1). It was also reported by Olsson (1975) and Maltz et al. (1984) that the consequences of water deprivation were hyperosmolality and hypovolemia and these changes stimulated thirst in water-deprived goats.

In the present study, the cumulative feed intake was linearly and negatively correlated to the increase in plasma osmolality and positively correlated to the decrease in plasma volume. In agreement with previous findings (Langhans et al., 1991), changes in plasma osmolality have sometimes been related to feed intake in goats. While hypoosmotic cues appear to stimulate feeding (Kakolewski and Deaux, 1970), plasma hypertonicity or hypovolemia can effectively suppress feeding in rats (Gutman and Krausz, 1969). Thus, the increasing of plasma osmolality and the decreasing of plasma volume observed in the present study might contribute to the decreasing of feed intake during water deprivation. The effects of water deprivation in the present study increased plasma protein and hematocrit concentration (see table 1). These changes were simultaneous with the decreases of plasma volume in water-deprived goats (table 1).

In conclusion, a decrease of feed intake during water deprivation is mainly due to an increase of quantitative thirst level, and the act of feeding itself induces thirst more than the length of water-deprivation periods in goats fed on dry feeds. Moreover, the thirst level can be affected by changes in plasma osmolality and plasma volume. The present findings suggest that plasma osmolality and plasma volume are involved in the decrease of feed intake in water-deprived goats.

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