GRAZING BEHAVIOR OF LACTATING AND NON-LACTATING YAKS IN THE SUMMER SEASON OF THE QINGHAI-TIBETAN PLATEAU

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ABSTRACT

The effect of the physiological states of lactating vs. non-lactating (dry) on grazing behavior and herbage intake by yaks was examined in the summer season in the Qinghai alpine area under continuous stocking management. Intake rates were estimated over periods of 1 h by weighing the animals before and after grazing, retaining the feces and urine excreted, and applying a correction for insensible weight loss (the 1-h weight changes of yaks when non-eating before or after the intake rate measurement). It is hypothesized that the lactating yaks should eat more and spend more time eating than non-lactating yaks, because they expend more energy. In our experiment, there were no differences in the effect of physiological state (lactating vs. dry) of yaks observed on the rate of insensible weight loss, intake rate, grazing jaw movement rate, bites per grazing jaw movement, or bite mass. The dry yaks tended to eat more and spend more time eating than lactating yaks, but not significantly so. Compared with the dry yaks, the lactating yaks had a significantly lower bite rate and bites per bolus.

Keywords: yak, grazing, ruminating, behavior, lactating, non-lactating, Qinghai-Tibetan plateau

INTRODUCTION

The yak (*Bos grunniens*) lives predominantly on the "roof of the world", as the Qinghai-Tibetan plateau is often called. The plateau itself extends over 2.5 million square kilometers (about 1 million square miles) and was described by Miller (1990) as the most extensive high-elevation region on earth and the best grazing lands in all of Asia. The yak plays an important role on the Qinghai-Tibetan plateau, where it has been acclimated to the harsh environmental conditions in Alpine grassland. Yaks have many characteristics and attributes that may be regarded as adaptations to many factors: extreme cold; high altitude with low oxygen content of the air and high solar radiation; difficult, often treacherous terrain; and cyclical nutrition, with short growing seasons for

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grazing herbage as well as a variety of herbage. It must be regarded as one of the world's most remarkable domestic animals as it thrives in conditions of extreme harshness and deprivation while providing a livelihood for people.

Yak husbandry depends on the natural forage produced by alpine rangeland all year long. Plant growing seasons vary from 120 to 180 days, but the periods of relatively vigorous plant growth are even shorter than that. Wilted herbage provides some sustenance at other times of year, but not in sufficient quantity for their requirements. Due to herbage shortage during the long, harsh cold season, yaks suffer from inadequate feeds under the traditional farming system, resulting in low milk production and low fertility (Long et al., 2005). Yaks graze a wide variety of plant species: grass, coarse plants and sedges, and some shrubs. Yaks can graze long grass using their tongues, as is common for cattle, but they can also graze very short herbage, after the manner of sheep, by using their incisor teeth and lips. When the ground is covered with snow and ice, they break through the cover to the wilted grass beneath, using their hooves and heads. Yaks also graze rapidly and for long hours (Gerald et al., 2003). Many of the characteristics of the yak can be regarded as adaptations to these conditions, in which cattle have difficulty surviving. An appropriate grazing management of such alpine areas ensures not only forage, but also environment for a sustainable development. However, achieving good grazing management of alpine rangelands presupposes knowledge of how yaks interact with the vegetation.

Physiological state and energetic demands may greatly affect the foraging decisions of grazers. Previous work conducted with dairy cows (Gibb et al., 1999) has shown that lactating cows, with their greatly elevated energetic expenditures, eat more at pasture than dry cows by increasing the time spent grazing at the expense of reducing ruminating time, rather than by an ability to significantly overcome the constraints on bite mass, bite rate, and intake rate imposed by the sward state. Penning et al. (1995) have shown that sheep are able to alter their grazing time in relation to their physiological state.

Few studies have been done to investigate how the physiological state of yaks affects their grazing behavior in the extreme, demanding alpine environment that they inhabit. The objective of the present experiment was therefore to investigate the ingestive behavior of yaks in different physiological states (lactating and dry) with successive grazing conditions during the summer season of Qinghai-Tibetan plateau.

MATERIALS AND METHODS

STUDY SITE

The experiment was conducted from 20 July to 15 August 2005 in summer pasture of the San Jiao Cheng Sheep Breeding Farm on the Qinghai-Tibetan plateau, situated in the Qilian mountain valley in northwest China, N 37°17.604', E 100°15.826' at an altitude of 3546 m. There is an alpine climate, which is a plateau-continent with rainfall concentrated in July and August. Mean annual precipitation is around 327.1 mm and mean annual temperature is –0.5 to 0.1 °C. The climate is arid and cold, and there are two distinct seasons. The lowest temperature, in January, is about –31.7 °C, and the highest temperature, in August, is about 25.5 °C. The frost-free period averages 108 d. The soil type of this area is alpine meadow soil. The dominant species in this area are *Carex qinghaiensis* L. and *Kobresia Pygmaea* C (Wang et al., 2004).

ANIMALS

Six lactating and six dry yaks were selected from a herd of 43 animals for trial. On 25 July, three lactating yaks were released to pasture for behavioral recording after morning milking. The other three lactating yaks were released on 27 July. Then the behaviors of the lactating yaks were recorded again from 29 July to 1 August. From 2 August to 9 August, the dry yaks were recorded. The experimental animals were herded together with the rest of the herd. The yaks were left at pasture except during morning and afternoon milking.

SWARD MEASUREMENT

The main forage species' height was measured twice, on 23 July and 10 August, by taking 100 measurements at random sites. At the same time, the aboveground biomass was measured using a 50 × 50 cm quadrat. Two samples of herbage, estimated as representative of the sward horizon grazed by yaks, were collected by hand during the time that intake rate (IR) measurements were being made with yaks. Samples were placed directly into pre-weighed polythene bags. One sample was subsequently dried in a forced draft oven at 60 °C for 24 h, then combusted in a muffle furnace to calculate dry matter (DM) and organic matter (OM) contents, respectively. The remaining sample was wind-dried at room temperature before determination of the acid detergent fiber (ADF) and neutral detergent fiber (NDF) content and crude protein (CP).

BEHAVIORAL MEASUREMENTS

Measurements of grazing behavior were determined using solid-state behavior recorders (Rutter et al., 1993, 1997), developed by IGER (Institute of Grassland and Environmental Research). After milking in the morning, three yaks were fitted with solid-state behavior recorders to record their temporal patterns of grazing, ruminating, and idling behavior over 24 h. On day 3, the alternate trio of yaks was fitted with recorders for 24 h.

Behavior recordings were analyzed using the software "Graze" (Rutter, 2000). The IGER-recorder can record the following data over 24 h (through analysis and calculation): total grazing time, total eating time, grazing jaw movements, total grazing bites, number of meals, total ruminating time, number of ruminative boluses, ruminative mastications, and total jaw movements. The jaw movement parameters were set as follows: min. jaw movement size (adc units) 25, min. prehension sub-peak (adc units) 4, min. inter-jaw movement interval (1/20 s): 14. Graze software uses three criteria to decide whether or not a particular waveform peak is a jaw movement. The jaw movement size is specified in adc units—the amplitude of a waveform from the top of the peak down to the lowest trough associated with the peak. The total eating time (TET) was calculated as the sum of the periods of grazing jaw movement (GJM), excluding intervals of jaw inactivity >3 s. Total grazing time (TGT) was the sum of the periods of GJM, including the periods of jaw inactivity <5 min. The number of meals was calculated as the number of periods of grazing activity separated by intervals of >5 min. Total idling time was calculated as the time within each 24 h when cows were not grazing and ruminating and included drinking and social interactions (Gibb et al., 1999). Bite rate (BR) was the mean bites per minute of herbage eating time. The time base employed was TET.

The number of biting and non-biting GJM during eating and the number of mastications during ruminating were counted automatically. The term "non-biting GJM" refers to those jaw movements made during grazing that are not identified as bites and therefore includes movements that may have a masticative or manipulative function (Gibb et al., 2002).

Calculation of intake rate (IR) used the short-term weight change method described by Gibb et al. (1997). In calculating IR, the time base employed was eating time, rather than grazing time, since the latter would have led to inclusion of intra-meal intervals (Gibb et al., 1999). IR was measured by weighing the yaks before and after each 1-h period using an electronic balance (Ruddweigh 300, manufactured by Ruddweigh Australia Pty Ltd.) with accuracy ±1%. A correction was needed for insensible weight loss (IWL), and it is important to measure IWL immediately before or after measurement of IR (Gibb et al., 2002). Because the yaks spent most of the morning grazing, IR and IWL were measured during the morning, at 8:30 and 9:30, respectively. Measurements of IWL were conducted over approximately 1 h, prior to the start of the late-morning grazing meal, followed immediately by measurement of IR (Gibb et al., 2002). Organic matter intake rate (OM IR, g min^{-1}) was calculated using the DM and OM contents determined from plucked grass samples. Bite mass (BM, g DM, and OM per bite) was calculated from the intake of herbage eaten and the number of bites during measurement of IR.

STATISTICAL ANALYSIS

Statistical tests were performed using SPSS version 10.0 (SPSS Inc., Chicago, IL, USA). A MANOVA was used to determine the effects of different physiological states on grazing behavior. The mean of behavioral data from the two recordings of the same yak in each period was used as the unit of replication because individual animals within a group cannot be regarded as statistically independent (Rook and Penning, 1991). In all statistical analysis of the data, between-pair variance was used as the error term. Comparison of means having a significant F-test was done using Duncan's Multiple Range Test (Steel and Torrie, 1987).

RESULTS

In the summer season, the herbage has a short green duration from the end of June to the beginning of September. Yaks grazed in summer pasture from 14 July to 25 August in 2005. The mean sward aboveground DM over the experiment was 91.96 ± 4.96 g/m^2 ± SE. The DM contents of *Kobresia humlis*, *Kobresia pygmaea*, and *Carex qinghaien-*

sis were 81.6, 14.7, and 13.1 g/m^2, respectively. The heights of the three species were 3.8, 4.9, and 3.7 cm, respectively. The chemical compositions of species appear in Table 1.

There were no significant effects ($p > 0.05$) of the yaks' physiological state on the rate of IWL, IR, total GJM rate, BR, and BM (Table 2). Dry yaks, however, had higher bites per GJM ($p = 0.050$) than the lactating yaks.

The recordings of yak physiological state on ingestive behavior over 24 h are shown in Table 3. Total grazing and eating time, total ruminating time, and total idling time were not affected ($p > 0.05$) by the physiological state of yaks. Compared with dry yaks, the lactating yaks had a lower BR ($p = 0.011$). Total GJM ($p = 0.346$) and total bites ($p = 0.122$) of lactating yaks tended to be lower, but not significantly so. Mastications per

Table 1
The DM, OM, CP, and ADF content of plucked samples; (DM, CP, and ADF were based on air-dried samples and OM was based on DM) (mean ± SE)

	DM (%)	OM (%)	CP (%)	ADF (%)	NDF (%)
Kobresia humlis	52.39 ± 0.42	91.70 ± 0.33	9.38 ± 0.11	32.08 ± 0.70	57.57 ± 0.99
Kobresia pygmaea	57.35 ± 0.28	92.3 ± 0.22	10.6 ± 0.31	30.13 ± 0.26	63.08 ± 0.48
Carex qinghaiensis	50.27 ± 0.31	93.8 ± 0.14	7.42 ± 1.66	33.77 ± 0.32	65.00 ± 0.18

Table 2
Effect of physiological state (PS, lactating vs. dry) on the rate of IWL, IR, GJM rate, BR, bites per GJM, and BM by grazing yaks measured over 1 h (mean ± SE)

	Lactating	Dry	Significance of effect of PS (*p* =)
Rate of IWL (g min^{-1})	19.66 ± 6.48	30.61 ± 6.54	0.300
IR (FM, g min^{-1})	44.45 ± 9.9	57.34 ± 1.18	0.266
IR (DM, g min^{-1})	16.45 ± 3.67	20.07 ± 0.41	0.381
Total GJM rate (GJM min^{-1})	46.02 ± 1.38	45.23 ± 0.37	0.609
Bites per GJM	0.89 ± 0.01	0.95 ± 0.02	0.050
BM (FM, g bite^{-1})	1.11 ± 0.27	1.34 ± 0.01	0.451
BM (DM, g bite^{-1})	0.41 ± 0.10	0.47 ± 0.01	0.582

bolus of lactating yaks were significantly lower ($p = 0.006$) than those of dry yaks. These differences in ingestive behavior coincide with a nominal (nonsignificant) tendency for IR to be lower for lactating yaks, compared with dry yaks (Table 2).

DISCUSSION

The experimental design and analysis were constrained by the numbers of suitable yaks available and the degree of independence between replicates, and were also constrained by the effect of social facilitation on the behavior of yaks during measurements.

Gibb et al. (1999) determined that lactating cows eat more at pasture than dry cows under continuous stocking management, and that the lactating cows extend their grazing time in order to meet their increased nutritional demand. However, the results of measurements in the present experiment showed the converse. The dry yaks tended to eat more and to extend their eating time compared with lactating yaks, though not significantly so in the statistical analysis. Because the lactating yaks should yield milk in this period, they had to expend more energy than dry yaks. Thus we expected the lactating yaks to eat more in order to satisfy their nutritional demand and to spend more time grazing. But under the conditions of low herbage mass and short sward height, the situation was different. When the forage was scarce, all the yaks spent large amounts of time

Table 3

Effect of physiological state (PS, lactating vs. dry) on behavior by grazing yaks measured over 24 h (mean ± SE)

	Lactating	Dry	Significance of effect of PS ($p =$)
Grazing behavior			
Total grazing time (min)	664 ± 22.16	691 ± 102.35	0.683
Total eating time (min)	587 ± 22.45	635 ± 85.68	0.449
Total GJM	27242 ± 1142.38	30122 ± 3399.21	0.346
Total bites	23721 ± 1045.50	28226 ± 3338.34	0.122
Non-biting GJM	3522 ± 374.59	1895 ± 118.51	0.078
Number of meals	11 ± 1.02	7 ± 3.21	0.192
BR (bites min^{-1})	40.3 ± 0.64	44.6 ± 0.80	0.011
Ruminating behavior			
Total ruminating time (min)	412 ± 23.67	416 ± 59.48	0.954
Total boluses	531 ± 38.26	390 ± 64.96	0.143
Total mastications	25271 ± 1575.59	24699 ± 3405.08	0.884
Mastications per bolus	48.3 ± 1.65	64.9 ± 8.68	0.006
Idling behavior			
Total idling time (min)	441 ± 37.97	389 ± 53.16	0.573
Total jaw movements	55017 ± 2140.56	56718 ± 4420.12	0.749

Numbers within rows followed by different letters are significantly different at the 5% level.

grazing at the expense of other activities. However, the calves were isolated from their mothers (lactating yaks), thus avoiding suckling except in the morning and afternoon milking. The lactating yaks do not concentrate so much on eating when away from their calves. Our observations suggest that lactating yaks appeared to wander more than dry yaks, especially when immediately removed from their calves, which was also reflected by the significantly lower BR of lactating yaks than dry yaks ($p = 0.011$) (Table 3).

In alpine areas, the growing season is very short (from 120 to 180 days), and the vigorous growing period for the vegetation is even shorter. The forage further becomes wilted, with very low quantity and quality (low protein content and high fiber content). We suggest that the yaks are adapted to grazing at a maximum capacity in the growing season (e.g., summer) in order to lay down as much fat as possible for the dry season (e.g., winter or early spring). So both lactating and dry yaks spent much more time eating during the summer season (9.8 h and 10.6 h) (Table 3). Generally, dairy cows spent from 5 to ~9 h eating over 24 h (Arnold et al., 1978). On the other hand, the dry yaks had to obtain much more nutrients for pregnancy in the coming spring season (in March or April), so the lactating yaks did not show longer eating times than did the dry yaks in the summer season.

During grazing, BM is largely determined by sward state variables, such as sward surface height (Gibb et al., 1996, 1997) and herbage bulk density within the grazed horizon (Laca et al., 1992; McGilloway et al., 1997). The yak physiological states had no significant ($p = 0.582$) effect on BM DM in our experiment (Table 2). As Gibb et al. (1999) showed, sward surface height has little effect on BM by cows on short swards as normally maintained under continuous stocking management. Nevertheless, there was a nonsignificant trend towards increased ($p = 0.381$) IRDM by the dry yaks compared with the lactating yaks (Table 2). The lack of significant differences in IR, GJM rate, bites per GJM, or BM suggests that the yak physiological states did not induce the animals to graze more "intensely" when grazing the short swards under continuous stocking management. This agrees with the results of Gibb et al. (1999).

Examination of behavior recorded over 24 h showed that both dry and lactating yaks spent long hours grazing each day (Table 3). We suggest that under these conditions energy is extremely valuable to all yaks, and that even the low harvest rates offered by the short sward were sufficient to cause the yaks, regardless of physiological state, to graze as long as conditions permitted. Thus, yaks increase their grazing time in order to obtain enough forage to compensate for the low intake rates constrained by low herbage mass and low sward height in the summer period. This is in contrast to cows in artificial pasture, where lactating cows eat more than dry cows by increasing the time spent grazing. Under harsh environment, with insufficient forage supplied, the eating time of yaks in different physiological states (dry and lactating) did not show significant differences (Table 3). Although there was also no significant difference in the ruminating time between lactating and dry yaks ($p = 0.954$), mastications per bolus was significantly lower in lactating yaks than in dry ones ($p = 0.006$) (Table 3). Thus, it would appear that in order to increase intake, lactating yaks reduce comminution through ruminative mastication in order to spend more time grazing.

CONCLUSIONS

In the extreme alpine area of the Qinghai-Tibetan plateau with its harsh environment and sward conditions, the physiological state of yaks (lactating or dry) has almost no effect on ingestive behavior in summer pasture. In order to obtain much more intake, the yaks increased the time spent grazing over 24 h at the expense of other activities. Dry yaks tended to spend more of their time grazing over 24 h, compared equally with lactating yaks, and no significant difference was found. However, lactating yaks took fewer bites and processed those bites less thorougly than did dry yaks. Through the results we obtained, in order to maintain body status and obtain enough milk production from lactating yaks, supplements should be given under the alpine sward conditions. On the other hand, the amount of livestock should be reduced in order to maintain good sward condition and avoid serious grassland degradation.

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