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Feeding behaviour of yaks on spring, transitional, summer and winter pasture in the alpine region of the Qinghai–Tibetan plateau

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Abstract

Of the present estimated world population of 14.2 million yaks, approximately 13.3 million occur within Chinese territories (Food and Agriculture Organization of the United Nations, 2003). Although there is an extensive bibliography covering the species, few studies have been conducted in the area of foraging behaviour. The present study was conducted at pasture during the spring, transitional, summer and winter seasons to determine the daily temporal patterns of grazing and ruminating behaviour by yaks. During each study period, two 24 h recordings were undertaken with each of six mature dairy yaks. One study period was conducted on each of the transitional, summer and winter pastures, whereas, due to the considerable changes occurring in the morphology of the spring pasture, three separate studies were completed during March, April and May. During the second of these studies (April), the effect of level of concentrate supplementation on grazing and ruminating behaviour was also examined. Behaviour recordings were made using solid-state behaviour recorders. Short-term intake rates (IR, g min^{-1}) were calculated by weighing yaks before and after approximately 1 h of grazing, retaining the faeces and urine excreted and applying a correction for insensible weight loss. Yaks spent less time grazing during the dry season (the early period on the spring pasture) compared with the later green swards (the later period on the spring pasture, the transitional pasture and the

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summer pasture) ($P < 0.05$). When the forage quality improved, but there was still insufficient mass (the later period on the spring pasture), the yaks extended their grazing time at the expense of other activities. During the early periods on the spring pasture, the short-term IR by yaks was up to 53 g DM min^{-1}, significantly higher than at other times ($P < 0.05$). The level of concentrate offered had little or no effect on grazing or ruminating time. The total eating time of the yaks offered 0.5 or 1.0 kg concentrate was 2.9 and 4.5 h day^{-1}, respectively, significantly lower than unsupplemented yaks (6.8 h) ($P < 0.05$). In general, yaks can regulate their foraging behaviour according to the changes of sward conditions in order to achieve optimal grazing strategies.

Keywords: Yak; Grazing; Ruminating; Behaviour; Supplementation

1. Introduction

On the Qinghai–Tibetan plateau, China, yaks (*Bos grunniens*) are essential for providing meat, milk, skins, transport and fuel (faeces), and fulfill various socio-cultural functions within the pastoral society. However, due to their relatively restricted worldwide distribution and population number of 14.2 million, yaks have been the subject of considerably less research than the ubiquitous and more numerous common domesticated cattle (*Bos taurus*; 1291 million).

Grazing systems represent approximately 20% of the total land area of the earth's surface (Hodgson and Illius, 1996). Herbivore utilization of grass swards is limited by the quality and quantity of forage ingested (Fryxell, 1991; Ungar, 1996), and the interaction between the grazing animal and sward has important implications for the development of both. Therefore, quantifying diet selection, herbage intake and modification of the forage resource by the grazing animal will help to define limits to sustainable grazing systems on the Qinghai–Tibetan plateau, rather than present practices which have led to serious degradation of the pastures. High stocking rates and the over-utilization of these alpine grasslands are the main cause of this grassland degradation.

Behaviour studies have played an important role in the improvement of grazing management throughout much of the world (Goldson, 1962). Grazing behaviour is important because of the immediate effect on the animal's productivity and because of its consequences for future grazing opportunities, composition of pasture and productivity (Coates and Penning, 2000).

The yak is a specialized species that has adapted to living in harsh and high altitude environments. The majority of the world population of yak occurs on the high plateau of western China in alpine and sub-alpine regions with a cold and semi-humid climate. The centre of the yak's distribution is the Qinghai–Tibetan plateau. The objectives of this work were to assess the feeding behaviour of yak grazing on Qinghai–Tibetan rangeland on spring, transitional, summer and winter pastures. In addition, the effect of providing a concentrate supplement during the spring season on yak foraging behaviour, when herbage was depleted, was examined.

2. Materials and methods

2.1. Location

Qinghai Lake grassland is typical of the alpine grassland of the Qinghai–Tibetan plateau. It is an important pasturing area for yak and sheep production, with a seasonal migration between different grazing areas. Typically, four pasture types are utilized over the year: spring, transitional, summer, autumn and winter pasture, with spring and winter pastures belong to one type, but divided by fences as different seasonal pastures. Before moving from spring pasture to summer pasture, the yaks are kept on a pasture for about 1 month in June and July, which is traditionally called transitional pasture. Because the sward is just germinating from May to June, there is a lack of forage in this period. However, there are good sward conditions in transitional pasture compared with other pastures because of sufficient groundwater. The transitional pasture plays a role for reducing the stock capacity of other pastures. On Qinghai–Tibetan plateau, the growing season is not very long (from May to October) and, because of the cold climate throughout the year (alpine climate), the grasses also have a low growing rate. Consequently, a greater area of pasture is retained for the winter–spring pasture; an area of 19000 ha. The areas of the summer, transitional and autumn pastures are 6000, 2000 and 3000 ha, respectively. Except for the transitional and summer pastures, other pastures were divided into sub-pastures by fences.

The spring pasture is provided during March, April and May, by an area of arid grassland with sparsely dispersed forage species. The dominant pasture species in this pasture are *Achnatherum splendens*, *Carex qinghaiensis* and *Kobresia pygmaea*. The transitional pasture abuts the spring pasture, but lies near the near bank of Qinghai Lake and is marshland. The yaks usually graze in the summer pasture from July to August every year. The summer pasture lies in the Qilian mountain valley and is also marshland, but has a warm climate with the mean temperature 18.3 °C at this time of the year. The dominant pasture species of the transitional and summer pastures are *C. qinghaiensis* and *K. Pygmaea*. The winter pasture is a flat area, and adjacent to the spring pasture. Generally, the yaks graze in the winter pasture from November to February of the next year. The senescent *C. qinghaiensis* is the dominant species, and no *A. splendens* is present on winter pasture.

The climate of this area is that of a plateau-continent, with the annual rainfall of 327 mm occurring mainly during July and August. Mean annual temperature is −0.5 to 0.1 °C, and the pasture-growing season is from May to October. The experiment was conducted between March and December 2005 at San Jiao Cheng Sheep Breeding Farm on Qinghai–Tibetan plateau, situated in northwest China, Qinghai Lakeside (37°16.212′N, 100°15.700′E), at an altitude of 3293 m.

2.2. Experimental design

2.2.1. Animals and the design in spring, transitional, summer and winter pastures

The same six mature, lactating yaks (Huanhu yak) of approximately the same age (7–8 years old) and live weight (about 200 kg) were selected from a herd of 24 animals for each study period, and were appropriately marked for identification. All the experimental yaks were in the same lactation phase. On the spring pasture, the yaks were manually milked once per day because of lack of forage, at around 9:00 h. On transitional and summer pastures, the yaks were manually milked twice per day, around 9:00 h and around 19:00 h.

Behaviour was recorded over 24 h using a solid-state recorder (IGER-recorder, Ultra Sound Advice, London, UK) on two occasions (in the morning or in the evening) in each seasonal period study. It took the yaks about 2 weeks to become accustomed to being fitted with, and wearing the recorders. The recorders were fitted to the yaks after milking in the early evening, with the exception of the summer pasture study, when they were fitted after morning milking. The daylight length was shorter in early spring and the nutritional demands of lactation had fallen because the yaks had calved in this period. Because of the limited number of solid-state recorders available (three recorders), the six yaks were recorded in two groups. The experimental animals remained with the rest of the herd throughout the periods of study. The whole herd remained at pasture throughout, except during milking and the concentrate experimental period. The stocking rates during the experimental periods on spring, transitional, summer and winter pastures were 11, 18, 14 and 12 sheep units ha^{-1} (1 yak = 4 sheep units).

The behaviour study was conducted using a randomized complete block design during three 20-day periods from 15 March to 25 May on spring pasture. During these periods, a vegetation survey was also carried out. The yaks were stocked on the transitional pasture between 25 May and 15 July, and foraging behaviour was recorded during two 15-day periods from 1 to 15 June and from 26 June to 10 July. The yaks were stocked on the summer pasture, from 20 July to 25 August (the yaks were moving from transitional pasture to summer pasture between 16 and 20 July) and studies were conducted between 27 July and 23 August, excluding wet days. The yaks were stocked on autumn pasture between 25 August and 15 October, but no data were obtained in this season due to communication problems with the recorders. The yaks were stocked on the winter pasture between 15 October and 25 February and the studies were conducted from 10 November to 8 December.

2.2.2. Feeding of concentrates at different levels on spring pasture

The effect of level of concentrate supplementation on the grazing and ruminating behaviour of yaks was examined during the second behaviour measurement period (April) on the spring pasture. A supplement level of 4 × 4 yaks Latin square design was employed. The four levels of supplementation were 0, 0.5, 1.0, 2.0 kg day^{-1} of a pelleted concentrate, which was produced by Qinghai Sanjiaocheng Sheep Breeding Farm and contained 20% oat hay, 35% wheatgrass hay, 20% maize, 15% wheat, 8% rapeseed, 1% fat, 0.2% mineral mix, 0.3% soybean meal, 0.1% vitamin, 0.2% amino acid, and 0.2% carrier, on a dry matter (DM) basis. The yaks were briefly penned with individual troughs during the afternoon for concentrate feeding. When the yaks ceased eating, they were released and any food refused, was collected and weighed. Samples of the concentrate were collected for analysis of crude protein (CP) content by the Kjeldahl method (Li et al., 1983). Acid-detergent fibre (ADF) and neutral-detergent fibre (NDF) content were determined using the methods described by Van Soest et al. (1991). The mean CP, ADF, NDF of the concentrate diet were 9.32, 0.35 and 0.89%, respectively.

2.3. Measurement of herbage mass, sward height and chemical composition

Herbage mass (kg DM ha^{-1}) was measured by cutting all herbage to ground level (excluding *A. splendens* on spring pasture because of its very long stems) from 20 randomly sited quadrats (50 cm × 50 cm) on the grazing area in each experimental period on spring, summer and winter pastures. Because the transitional pasture was marshland, the herbage was cut level with the water surface. The samples were crushed through 1 mm sieve and dried at 105 °C for 6 h to determine dry matter weight. The vertical height of the dominant species was measured with a ruler by taking measurements at 100 random sites in each pasture. Ten samples of herbage, estimated as representative of the sward grazed by yaks, were collected by hand during the time that short-term intake rate (IR) measurements were being made with yaks. Samples were placed directly into pre-weighed polythene bags to retain moisture. After weighing the fresh herbage in the bags, one sample was subsequently dried in a forced draught oven at 60 °C for 24 h and weighed, then combusted in a muffle furnace to calculate DM and organic matter (OM) contents, respectively. The remaining sample was air dried at room temperature (avoiding direct sunlight) before determination of ADF, NDF and CP content.

2.4. Measurement of grazing behaviour

Measurements of grazing behaviour were determined using solid-state behaviour recorders (Rutter et al., 1993, 1997). After milking, the yaks were fitted with the recorders to record their temporal patterns of grazing, ruminating and idling behaviour over 24 h. Six yaks were consecutively recorded twice during each seasonal study. During each study period, the six yaks used for behaviour measurements were weighed each day at 09:00 h.

Behaviour recordings were analysed using the software 'Graze' (Rutter, 2000). Interpretation of the recorded data was conducted following the protocol described by Gibb et al. (1999, 2002). Grazing jaw movement (GJM) refers to jaw movement associated with the process of eating, including manipulatory, prehensile, biting and chewing movements. Eating time and grazing time were distinguished in order to analyse the yak grazing behaviour more precisely. Eating is an activity involving the taking of herbage into the mouth, its mastication and subsequent swallowing. In contrast, grazing is an activity including short periods when the animal is not actively eating, but is engaged in activity directly associated with eating, such as searching or moving from one patch of sward to another. The total eating time (TET) was the periods of GJM, including intra-meal intervals less than 3 s. Total grazing time (TGT) including all the periods of GJM, including any periods of jaw inactivity less than 5 min. Total ruminating time was the sum of the periods of ruminating jaw movement, including intervals during ruminating activity less than 20 s. The number of biting and non-biting GJM during eating, and the number of mastications (total mastications) during ruminating were counted automatically by the recorder. The term 'non-biting GJM' refers to those jaw movements made during grazing that are not identified as bites, and therefore, includes movements which may have a masticative or manipulative function. Bite rate (BR) was bites per min. TET is the time base used to calculate BR. Total jaw movements include GJM, non-biting GJM, mastications when ruminating and undetermined jaw movements. The number of meals was calculated as the number of periods of grazing activity separated by intervals of less than 5 min. Total idling time was calculated as the time within each 24-h period when yaks were not grazing or ruminating.

Whilst the 'Graze' software cannot automatically distinguish between eating concentrates and forage, Gibb et al. (2002) has shown in a previous study with dairy cows that the two behaviours can be readily distinguished visually by the characteristic recorded wave patterns they produce. A similar distinction could be made in the present study (Fig. 1), although the wave patterns produced when eating concentrate diets were different from those with dairy cows, there being no double peaks produced in the yak patterns.

2.5. Measurement of short-term intake rate

Intake rate was calculated using a short-term weight-change technique described by Gibb et al. (1997). Intake of fresh herbage was measured by weighing the yaks before and after a 1-h period of grazing, using an

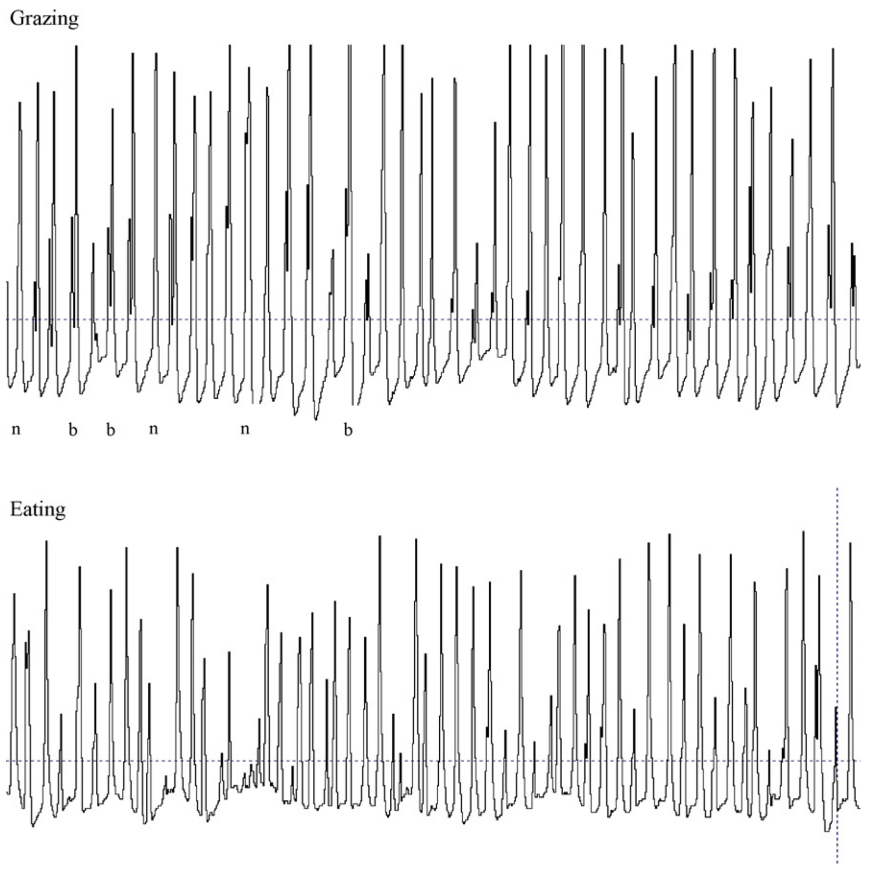

Fig. 1. Wave patterns of recorded grazing and eating of concentrate diets. Grazing shows a mixture of bites typified by large secondary peaks (b), and non-biting jaw movements without secondary peaks (n). Eating concentrates typically shows a pattern without secondary peaks.

electronic balance (Ruddweigh 300, International Scale Company Pty Ltd., Guyra, NSW, Australia, with a 2000 kg weighing capacity and accuracy. $\pm 1\%$). However, correction of intake was required because of the animal's insensible weight loss (IWL), which varies during the course of a day due to fluctuations in air temperature and relative humidity (Nuthall et al., 1994). Thus, measurement of IWL should be made over a period (about 1 h), either immediately before or after the period of intake measurement (Gibb et al., 2002). In addition to the rate of IWL, grazing behaviour also varies with time of day (Gibb et al., 1998), and IR (DM g min^{-1}) and bite mass (BM) can increase during the afternoon due to an increase in the DM content of leaves (Gibb et al., 1999).

In the present study, the yaks spent most of their time grazing during the morning, so IR and IWL were measured during the morning over 1-h periods commencing at 8:30 and 9:30 h, respectively. And no measurements were done in the afternoon. During periods of IWL and IR measurement, yaks were fitted with harnesses and excreta collection bags to collect faeces and urine so that these losses could be determined. IWL was determined by weighing yaks at the start and end of a 1-h period (weights W_1 and W_2 at times t_1 and t_2, respectively). Immediately, the yaks were released onto pasture for 1 h grazing, and weighed again (weight W_3 at time t_3). IR was calculated as:

$$\text{IR} = (W_3 - W_2) + \frac{W_1 - W_2}{t_2 - t_1}(t_3 - t_2)$$

During the measurement of IWL, the yaks were kept in the pen (tied individually) in order to prevent eating. During measurement of IR, yaks were fitted with behaviour recorders and released onto the pasture to record actual eating time and the number of bites performed. Each time when the measurements of IR were conducted, three yaks were randomly selected from the six and used. In calculating IR, the time base used was eating time, rather than the time present on the pasture or grazing time, since the latter could have led to inclusion of non-grazing activity or intra-meal intervals, respectively (Gibb et al., 1999). BM (g bite^{-1}) was calculated from the weight of herbage eaten and the number of bites recorded during measurement of the short-term IR. IR and BM were calculated on a DM basis using the DM content determined on the herbage collected during the 1 h intake measurement period.

2.6. Statistical analysis

The mean values of the measured and derived variables (TGT, TET, total ruminating time, GJM and IR, etc.) for each group of yaks on each occasion were calculated and compared by analysis of variance using SPSS version 10.0 (SPSS Inc., Chicago, IL, USA). Because of the relatively long time intervals between measurements in each of the seasonal periods (at least 15 days) on the same groups of animals, the mean value for each set of measurements was regarded as independent. For each individual yak, the values derived in each study period were the arithmetic mean of those derived from the two observations. The 'trio' mean values (i.e. a mean of six values, from two observations on three yaks) were used in the ANOVA. Comparison of individual means for variates demonstrating a significant period effect was conducted using Duncan's Multiple Range Test (Steel and Torrie, 1980). When the effect of level of concentrate supplementation (spring pasture only) on grazing and ruminating behaviour was examined, a 4×4 Latin square design was used.

3. Results

3.1. Herbage mass, sward height and chemical composition

The herbage mass in period 1 (March), period 2 (April) and period 3 (May) on spring pasture, transitional pasture, summer pasture and winter pasture are shown in Table 1. The herbage mass was significantly higher in the dry periods (periods 1 and 2 on spring season, winter season) than in green periods (period 3 on spring season, transitional and summer seasons) ($P < 0.05$). The

Table 1
Herbage mass (kg DM ha^{-1}) of sward and swards' height (cm) on four pastures on Qinhai-Tibetan plateau (mean ± S.E.)

	Spring pasture			Transitional pasture	Summer pasture	Winter pasture
	Period 1	Period 2	Period 3			
Herbage mass	$1585.2^{a} \pm 1.07$	$1544.3^{a} \pm 0.28$	$376.8^{c} \pm 0.12$	$521.6^{c} \pm 0.65$	$852.1^{b} \pm 2.03$	$1429.1^{a} \pm 2.44$
Swards' height						
Achnatherum splendens	$65.41^{a} \pm 1.35$	$62.89^{a} \pm 1.26$	$55.41^{a} \pm 2.13$	–	–	
Carex qinghaiensis	$12.64^{a} \pm 0.53$	$12.30^{a} \pm 0.27$	$3.67^{c} \pm 0.33$	$5.56^{b} \pm 0.13$	$4.61^{bc} \pm 0.64$	$7.49^{a} \pm 0.81$
Kobresia pygmaea	–	–	$2.67^{c} \pm 0.24$	$3.67^{ab} \pm 0.05$	$4.88^{a} \pm 0.26$	
Kobresia humlis	–	–	–	–	3.76 ± 0.17	

Numbers within rows followed by different superscript letters (a–c) are significantly different at the 5% level (by Duncan test).

Table 2
The dry matter (DM), organic matter (OM), crude protein (CP), acid-detergent fibre (ADF) and neutral-detergent fibre (NDF) content of plucked samples of each pasture on Qinghai–Tibetan plateau (mean ± S.E.)

	DM ($g\,kg^{-1}$) fresh matter	OM ($g\,kg^{-1}$ DM)	CP ($g\,kg^{-1}$ DM)	ADF ($g\,kg^{-1}$ DM)	NDF ($g\,kg^{-1}$ DM)
In spring pasture					
In periods 1 and 2					
Achnatherum splendens	$951.7^{a} \pm 0.11$	$950.0^{a} \pm 0.07$	$40.7^{g} \pm 0.01$	$323.5^{a} \pm 0.37$	$579.5^{b} \pm 0.16$
Carex qinghaiensis	$944.4^{b} \pm 0.27$	$937.2^{b} \pm 0.21$	$54.4^{f} \pm 0.22$	$321.1^{a} \pm 0.13$	$550.9^{c} \pm 0.97$
In period 3					
Carex qinghaiensis	$287.9^{g} \pm 0.25$	$922.8^{d} \pm 0.16$	$117.1^{c} \pm 0.31$	$231.6^{e} \pm 0.43$	$468.2^{f} \pm 0.27$
Kobresia pygmaea	$258.4^{h} \pm 0.31$	$902.3^{e} \pm 0.35$	$126.1^{b} \pm 0.26$	$256.7^{d} \pm 0.25$	$537.4^{d} \pm 0.11$
In transitional pasture					
Carex qinghaiensis	$524.6^{c} \pm 0.16$	$908.6^{e} \pm 0.33$	$105.9^{d} \pm 0.28$	$250.7^{d} \pm 0.49$	$502.3^{e} \pm 0.08$
Kobresia pygmaea	$487.7^{d} \pm 0.22$	$926.1^{c} \pm 0.41$	$170.1^{a} \pm 0.20$	$275.8^{c} \pm 0.33$	$596.5^{a} \pm 0.07$
In summer pasture					
Carex qinghaiensis	$392.4^{e} \pm 0.30$	$937.7^{b} \pm 0.14$	$93.8^{e} \pm 0.11$	$278.3^{c} \pm 0.32$	$474.3^{f} \pm 0.07$
Kobresia pygmaea	$368.9^{f} \pm 0.28$	$923.4^{d} \pm 0.22$	$106.3^{d} \pm 0.31$	$219.7^{f} \pm 0.27$	$493.7^{e} \pm 0.23$
In winter pasture					
Carex qinghaiensis	$240.1^{i} \pm 0.21$	$874.3^{f} \pm 0.03$	$42.7^{g} \pm 0.30$	$297.1^{b} \pm 0.44$	$555.4^{c} \pm 0.28$

Numbers within columns followed by different superscript letters (a–i) are significantly different at the 5% level (by Duncan test).

height of the dominant species in the four pastures during the different periods is shown in Table 1. The height of *A. splendens* in period 1 on spring pasture was up to 65 cm. There are no *A. splendens* in transitional, summer and winter pastures. The height of *C. qinghaiensis* on early spring pasture (periods 1 and 2) was approximately 12 cm, significantly higher than on later spring season (period 3), transitional and summer pastures. The height of *K. pygmaea* was just 2.67 cm on late spring season (period 3), significantly lower than on transitional and summer pastures. The species of *Kobresia humlis* only occurred on summer pasture, with a height of 3.76 cm. The mean DM, OM, CP, ADF and NDF content of the plucked pasture samples are given in Table 2. Because the herbages were all dry in periods 1 and 2 on spring pasture, the herbage samples were mixed in these two periods for measuring chemical composition. The DM and OM contents of *A. splendens* in early spring season (periods 1 and 2) were significantly higher than other species' in different seasons. The *C. qinghaiensis* had the lowest DM and OM contents on winter pasture. The CP of herbages in growing seasons (period 3 on spring pasture, transitional and summer pastures) was significantly higher than in dry seasons (periods 1 and 2 on spring pasture and winter pasture). Contrarily, the herbages had higher ADF content in dry seasons than in growing seasons. The highest NDF content was found with *K. pygmaea* on transitional pasture.

3.2. Temporal patterns of grazing and ruminating

Examples of the temporal patterns of grazing and ruminative activity by two yaks during the six study periods are shown in Fig. 2. Because yaks are social animals, they show almost the same behaviour patterns as each other at the same seasonal times. On most occasions, the ruminating activities were performed at night. The grazing and ruminating patterns of yaks in early spring season (periods 1 and 2) contained many inter-meal intervals. However, there were less inter-

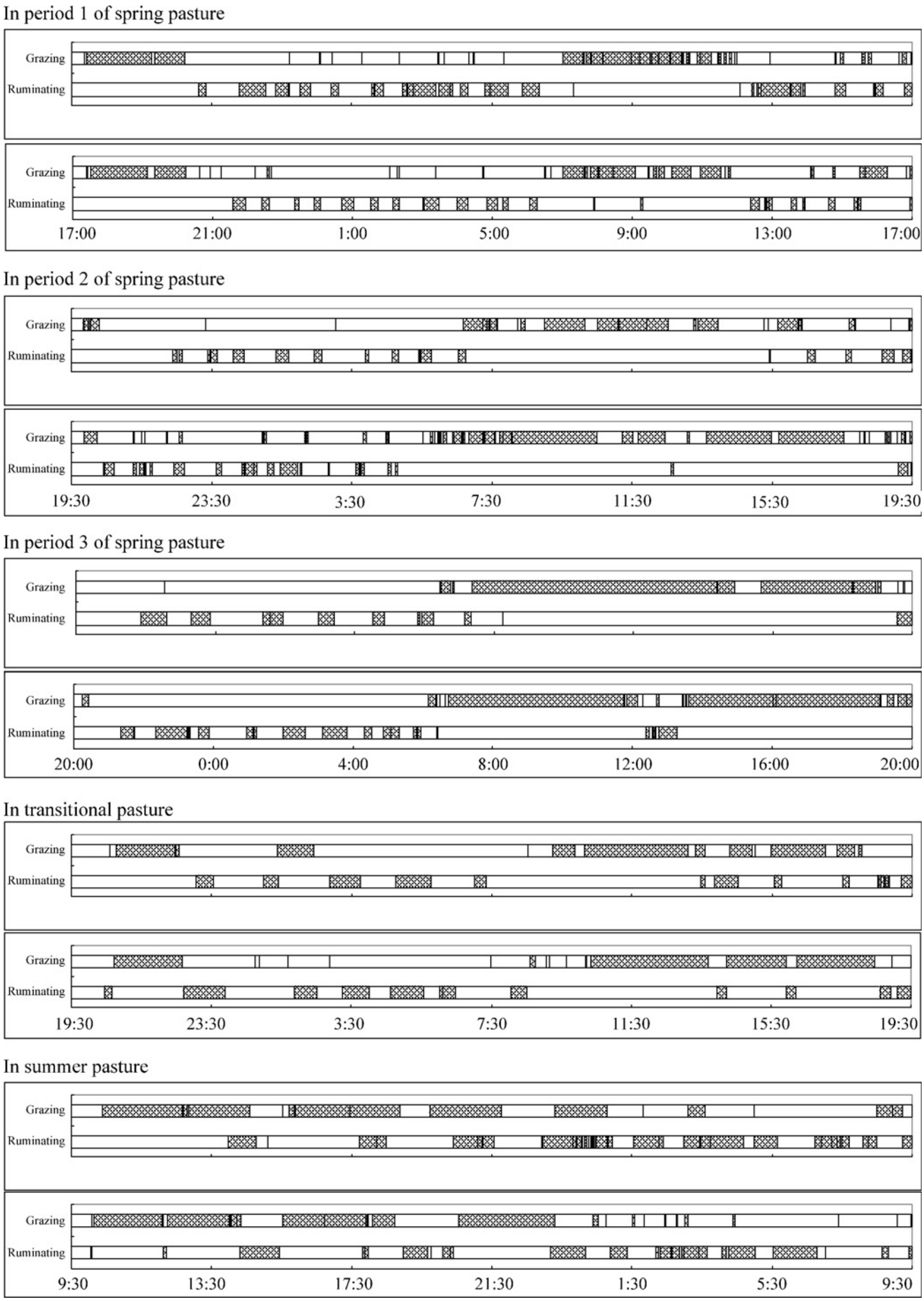

Fig. 2. Temporal patterns of grazing activity and ruminating activity by yaks measured over 24 h in three periods of spring pasture, in transitional, summer and winter pastures. The behaviour patterns of two yaks are shown in each period.

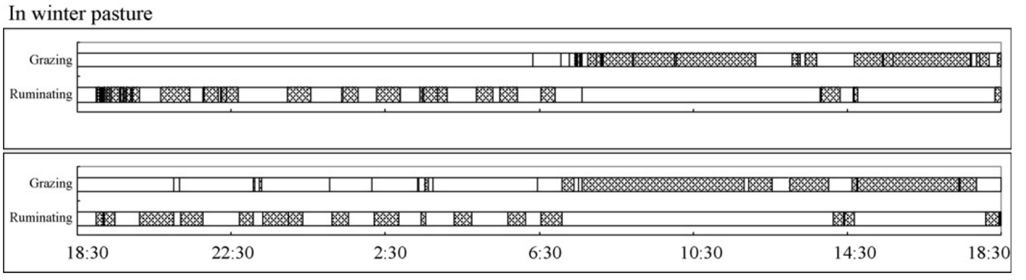

Fig. 2. (*Continued*).

meal intervals in late spring season (period 3) and most of the grazing activity occurred in the daytime from 6:30 to 20:00 h in late spring. The grazing activity was extended to midnight in transitional and summer seasons. There were also some ruminating activities in the daytime on summer pasture. The grazing activities were mainly observed in the daytime on winter pasture. The results of the 24 h behaviour recordings in the four seasons, with the component studies conducted on the spring pasture, are presented in Table 3. TGT by the yaks during period 3 on the spring pasture and on the transitional and summer pastures was significantly longer than on the early spring and winter pastures. TET on the late spring (period 3), transitional and summer pastures were also significantly higher than those recorded on pastures at other times of the year. Number of meals on early spring (periods 1 and 2) pasture was significantly higher than on late spring (period 3), summer and winter pastures, and the yaks had a lower number of meals in period 3 on spring pasture and summer pasture than on transitional pasture. The non-biting GJM on spring pasture were significantly higher than on transitional and summer pastures. The yaks had a significantly higher number of bites and higher BR (up to 66 bites min^{-1}) in period 3 on spring pasture than at any other time. Total ruminating time and the total number of boluses regurgitated were highest when the yaks were grazing on the summer pasture, and were significantly lower when grazing on the spring pasture during periods 2 and 3. Total mastications on summer pasture were significantly higher than on spring and transitional pastures and no significant difference was found with total mastications on spring, transitional, summer and winter pastures. The yaks had the highest number of mastications per bolus during period 1 on the spring pasture and on the winter pasture. The yaks spent the least time idling when they were on the summer pasture and the greatest proportion of their day was spent idling when they were on the spring pasture during periods 1 and 2. The bites, total GJM and total jaw movements were significantly higher in period 3 on the spring pasture than in other periods. The mean live weight of experimental yaks on winter pasture was 221 kg, significantly higher than on spring and transitional pastures.

3.3. Rates of intake and insensible weight loss

IR and IWL determined during the 1 h measurement periods are shown in Table 4. Despite a more than two-fold difference between the lowest and highest rates of IWL, no significant differences were established between measurements on the different pastures ($P > 0.05$). So IWL is not the key factor affecting the live weight changes of yaks when calculating IR under alpine climate and grassland conditions. The fresh matter (FM) IRs achieved by yaks on the spring pasture (periods 2 and 3) and on the transitional pasture were significantly higher than those achieved on summer pasture. However, dry matter IR on the spring pasture prior to

Table 3

Yak grazing behaviour measured over 24 h and the live weight on spring, transitional and summer pastures on Qinghai–Tibetan plateau (mean ± S.E.)

	Spring pasture			Transitional pasture	Summer pasture	Winter pasture
	Period 1	Period 2	Period 3			
Grazing behaviour						
Total grazing time (min)	366 ± 39.1^{c}	477 ± 47.7^{b}	676 ± 13.4^{a}	600 ± 20.7^{a}	664 ± 22.2^{a}	475 ± 27.0^{b}
Total eating time (min)	315 ± 44.4^{d}	398 ± 43.3^{cd}	643 ± 14.2^{a}	529 ± 15.6^{b}	587 ± 22.5^{ab}	439 ± 25.4^{c}
Total grazing jaw movements	$17,674 \pm 2687.2^{c}$	$22,989 \pm 2147.5^{b}$	$50,061 \pm 397.4^{a}$	$26,683 \pm 1040.6^{b}$	$27,242 \pm 1142.4^{b}$	$26,078 \pm 1718.9^{b}$
Bites	$11,058 \pm 1102.0^{d}$	$15,472 \pm 2474.6^{c}$	$42,423 \pm 1124.4^{a}$	$24,597 \pm 751.0^{b}$	$23,721 \pm 1045.5^{b}$	$20,844 \pm 1457.5^{b}$
Number of meals	12.8 ± 1.3^{a}	10.4 ± 1.2^{ab}	5.2 ± 1.0^{d}	9.3 ± 1.5^{bc}	5.0 ± 0.7^{d}	6.6 ± 0.8^{cd}
Non-biting grazing jaw movements	6615 ± 1924.0^{a}	7517 ± 440.3^{a}	7638 ± 788.8^{a}	2086 ± 367.1^{c}	3522 ± 374.6^{bc}	5234 ± 527.5^{ab}
Bite rate (bites min^{-1})	37 ± 2.8^{c}	38 ± 2.0^{c}	66 ± 1.0^{a}	47 ± 1.9^{b}	40 ± 0.6^{c}	47 ± 1.1^{b}
Ruminating behaviour						
Total ruminating time	317 ± 37.2^{ab}	239 ± 57.0^{b}	250 ± 24.2^{b}	268 ± 60.4^{ab}	412 ± 23.7^{a}	380 ± 33.6^{ab}
Total boluses	293 ± 50.3^{b}	235 ± 56.8^{b}	246 ± 26.2^{b}	247 ± 77.9^{b}	531 ± 38.3^{a}	308 ± 19.7^{b}
Total mastications	$15,466 \pm 1502.4^{b}$	$12,006 \pm 2835.2^{b}$	$12,970 \pm 1312.8^{b}$	$14,051 \pm 4425.9^{b}$	$25,271 \pm 1575.6^{a}$	$17,506 \pm 1134.9^{ab}$
Mastications per bolus	55 ± 3.6^{a}	52 ± 2.2^{ab}	53 ± 2.6^{ab}	49 ± 9.7^{b}	48 ± 1.7^{b}	57 ± 3.0^{a}
Idling behaviour						
Total idling time (min)	809 ± 71.1^{a}	803 ± 70.8^{a}	547 ± 23.7^{bc}	572 ± 73.7^{c}	441 ± 38.0^{c}	621 ± 48.8^{abc}
Total jaw movements	$36,532 \pm 3832.4^{c}$	$38,089 \pm 3659.2^{c}$	$64,268 \pm 1123.5^{a}$	$43,855 \pm 3096.8^{bc}$	$55,017 \pm 2140.6^{b}$	$45,029 \pm 2164.5^{bc}$
Live weight (kg)	159 ± 15.9^{b}	160 ± 15.3^{b}	168 ± 15.7^{b}	174 ± 11.2^{b}	202 ± 7.8^{ab}	221 ± 18.5^{a}

Numbers within rows followed by different superscript letters (a–d) are significantly different at the 5% level (by Duncan test).

Table 4
Short-term intake rate (IR), rate of insensible weight loss (IWL), and grazing behaviour of yaks measured over 1 h on spring, transitional, summer and winter pastures on Qinghai–Tibetan plateau (mean ± S.E.)

	Spring pasture			Transitional pasture	Summer pasture	Winter pasture
	Period 1	Period 2	Period 3			
IWL (g min^{-1})	31.1 ± 5.56	32.2 ± 10.29	19.4 ± 5.56	37.7 ± 7.95	19.7 ± 6.48	16.7 ± 3.41
Intake rate (FM g min^{-1})	78.0 ± 6.50^{ab}	91.1 ± 10.56^{a}	97.3 ± 28.73^{a}	110.4 ± 2.38^{a}	44.5 ± 9.92^{b}	67.1 ± 7.88^{ab}
Intake rate (DM g min^{-1})	53.2 ± 5.91^{a}	46.7 ± 8.83^{a}	27.2 ± 8.04^{b}	24.6 ± 0.53^{b}	16.5 ± 3.67^{b}	24.8 ± 2.91^{b}
Total GJM rate (GJM min^{-1})	59 ± 1.6^{b}	57 ± 0.7^{b}	72 ± 4.8^{a}	41 ± 6.6^{c}	46 ± 1.4^{bc}	55 ± 5.6^{b}
Bite rate (bites min^{-1})	41 ± 3.61^{bc}	40 ± 3.24^{bc}	58 ± 4.15^{a}	31 ± 1.63^{c}	41 ± 1.33^{bc}	50 ± 4.36^{ab}
Bites GJM^{-1}	0.69 ± 0.07	0.69 ± 0.05	0.82 ± 0.04	0.78 ± 0.08	0.89 ± 0.01	0.94 ± 0.16
Bite mass (FM g $bite^{-1}$)	1.94 ± 0.17^{bc}	2.37 ± 0.45^{b}	1.65 ± 0.50^{bc}	3.61 ± 0.25^{a}	1.11 ± 0.27^{c}	1.33 ± 0.07^{bc}
Bite mass (DM g $bite^{-1}$)	1.52 ± 0.16^{a}	2.20 ± 0.42^{a}	0.46 ± 0.14^{b}	0.80 ± 0.06^{b}	0.41 ± 0.10^{b}	0.49 ± 0.03^{b}

Numbers within rows followed by different superscript letters (a–c) are significantly different at the 5% level (by Duncan test).

germination (periods 1 and 2) were significantly higher than at any other time of the year ($P < 0.05$). There was no significant difference in dry matter IR achieved on the four different swards between May (spring pasture, period 3) and early December (winter pasture). The highest bite rate (58 bite min^{-1}) was recorded in period 3 of spring pasture, when the highest total grazing jaw movements (GJM) rate was also recorded. However, there were no significant differences in the bites per GJM. The highest fresh matter bite mass (BM) was achieved on transitional pasture, whereas the highest dry matter BM was achieved in the senescent pastures in periods 1 and 2 on the spring pasture.

3.4. Effect of level of concentrate supplementation on grazing and ruminating behaviour on spring pasture

In the present experiment, we observed that the yaks were able to consume their total ration within 10–15 min regardless of level. Analysis of variance showed no significant effect of level of supplementation on TGT or TET, although application of Duncan's Multiple Range test, using the individual period mean and standard errors, showed a significant difference in TGT and TET between 0 and 0.5 kg supplement levels (Table 5). When the concentrate level was 0 or 2.0 kg, the yaks had significantly higher total GJM than on the 0.5 or 1.0 kg level. The total bites in the 0.5 supplement level was significantly lower than in the 0 and 2.0 supplement levels. When there were no supplements, the non-biting GJM were significantly higher than supplement treatments and the non-biting GJM in 1.0 and 2.0 kg supplement levels were also significantly higher than in 0.5 kg level. Treatments did not significantly affect the number of meals and BR. There was no significant effect of treatment on the time spent ruminating or the number of ruminative mastications (total mastications and mastications per bolus). The total boluses in 0.5 kg level were significantly higher than in 2.0 kg level. When concentrate pellets were given, yaks spent more time idling compared with the unsupplemented individuals and performed fewer total jaw

Table 5
Effect of level of concentrate supplementation on grazing and ruminating behaviour by yaks measured over 24 h in spring pasture on Qinghai–Tibetan plateau (mean ± S.E.)

	Concentrate allowance (kg day^{-1} animal^{-1})			
	0	0.5	1.0	2.0
Grazing behaviour				
Total grazing time (min)	$494^{a} \pm 57.90$	$225^{c} \pm 19.82$	$343^{bc} \pm 42.94$	$433^{ab} \pm 30.06$
Total eating time (min)	$408^{a} \pm 54.48$	$174^{c} \pm 16.87$	$270^{bc} \pm 36.41$	$384^{ab} \pm 31.55$
Total grazing jaw movement (GJM)	$23{,}672^{a} \pm 2628.79$	$9278^{b} \pm 1009.39$	$14{,}289^{b} \pm 1980.69$	$21{,}675^{a} \pm 2143.79$
Total bites	$16{,}033^{a} \pm 3111.63$	7457 ± 925.78^{b}	$9828^{ab} \pm 1395.34$	$16{,}061^{a} \pm 1620.05$
Non-biting grazing jaw movement (GJM)	$7639^{a} \pm 546.27$	$1821^{c} \pm 332.88$	$4461^{b} \pm 801.66$	$5614^{b} \pm 593.77$
Number of meals	10.1 ± 1.3	12.0 ± 0.7	8.7 ± 0.9	11.3 ± 1.4
Bite rate (BR, bites min^{-1})	38 ± 2.57	41 ± 1.58	37 ± 1.89	42 ± 0.90
Ruminating behaviour				
Total ruminating time (min)	275 ± 57.55	303 ± 41.22	216 ± 41.39	240 ± 10.72
Total boluses	$271^{ab} \pm 56.45$	$348^{a} \pm 34.48$	$227^{ab} \pm 27.25$	$223^{b} \pm 22.68$
Total mastications	$13{,}826 \pm 2806.89$	$16{,}668 \pm 1758.66$	$10{,}187 \pm 2160.10$	$11{,}232 \pm 683.26$
Mastications per bolus	52 ± 2.86	48 ± 0.41	44 ± 4.45	51 ± 3.89
Idling behaviour				
Total idling time	$758^{b} \pm 70.59$	$963^{a} \pm 36.36$	$954^{a} \pm 23.90$	$816^{ab} \pm 41.57$
Total jaw movements	$40{,}862^{a} \pm 3083.41$	$29467^{b} \pm 1468.50$	$29{,}075^{b} \pm 864.14$	$35{,}364^{ab} \pm 2945.29$

Numbers within rows followed by different superscript letters (a–c) are significantly different at the 5% level (by Duncan test).

movements. When there were no supplements provided, the yaks had significantly higher total jaw movements than in 0.5- and 1.0-supplement levels.

4. Discussion

4.1. Grazing and ruminating behaviour

Grazing activity occurred mainly, though not exclusively, during the hours of daylight (range: 06:00–19:00 h, in spring and winter seasons, respectively). At night, yaks avoid grazing and tend to gather in groups in order to reduce body heat loss, because of the cold night temperatures, and as a defense mechanism against attack by predators. However, with the growth of new green herbage in May (period 3) on the spring pasture, and subsequently on the transitional and summer pastures, the yaks substantially increased their total grazing time (from <8 h to between 10 and 11.15 h day^{-1}).

During March and April (periods 1 and 2), spring pasture provided the yaks with a mixture of grass and sedge for grazing. The dominant species, *A. splendens*, is an index for degraded grassland (Zhou et al., 2006). It is regarded as a weed in grassland with a big, firm cluster and long stems. On the spring pasture, although plants of *A. splendens* are tall, they provide a poor source of food for livestock because of the slender, chlorotic leaves and lignified pseudostem, as exemplified by the low CP content (41 g kg^{-1} DM) and high-fibre content (324 g ADF kg^{-1} DM and 580 g NDF kg^{-1} DM). When alternative pasture species are present at other times of the year, yak will usually select these in preference to *A. splendens*. However, under the senescent pasture conditions prevailing in the early spring (March and April), yaks were willing to graze the dominant sedge species, *C. qinghaiensis*, similarly comprising senescent, low protein (54 g CP kg^{-1} DM), high-fibre (321 g ADF and 551 g NDF kg^{-1} DM) material. Nevertheless, during these 2 months, with heights of *A. splendens* and *C. qinghaiensis* exceeding 60 and 12 cm, respectively, yaks were able to achieve significantly greater DM bite masses (between 1.5 and 2.2 g $bite^{-1}$) and higher short-term DM intake rates (53 and 47 g DM min^{-1}, respectively) than at other times of the year. During the months of March and April the yaks grazed mainly during the hours of daylight, as discussed previously. During these times, yaks were only actively eating (i.e. TET) for about 315 and 398 min (Table 3), respectively, which represented 86 and 83% of TGT. With short day length and poor quality diet, yaks will spend more time searching or lying down to avoid cold weather and wind, especially at night, which may be reflected in the longer total idling time in early spring and winter seasons. Then the yaks had the highest number of meals during period 1 (12.8) and period 2 (10.4) of spring pasture.

By May (period 3) on the spring pasture, the height of *A. splendens* had been reduced to 55 cm and the senescent material of *C. Qinghaiensis* had been considerably reduced, with short (<4.0 cm) new shoots emerging (Table 1). However, according to our personal observations, by this time yaks were very reluctant to graze *A. splendens*. The reduction in the height of these species was also accompanied by the emergence of new shoots of *K. pygmaea*, although they had only reached a height of 2.7 cm by this time (Table 1). Whilst yaks can graze long grass using their tongues, as is common for cattle, they can also graze very short herbage, after the manner of sheep and cattle, by using their incisor teeth and lips. Nevertheless, as a consequence of the short herbage, BM of dry matter was significantly lower, i.e. proportionately less than 1.0–1.7 g of that in the previous 2 months (Table 4). In response, the yak significantly increased their bite rates from 40 to 58 bite min^{-1} when measured over 1 h (Table 4), and from 38 to 66 bite min^{-1}, when measured over 24 h (Table 3). Nevertheless, this was insufficient to fully compensate for the reduced BM, and the net result was a significant reduction in IR of DM, from 53 to 27 g min^{-1} (Table 4). To compensate for this reduction, yaks significantly increased TGT to more than 660 min (Table 3). TET also increased significantly, to 643 min each day (Table 3). This represented an increase in TET as a proportion of TGT to 0.95, probably achieved by a reduction in searching activity, facilitated by the improved homogeneity and availability of edible herbage. This is also reflected in the significant reduction of number of meals, from 10 in period 2 (April) to 5 in period 3 (May) of spring pasture. Although the increase in TGT and TET were probably insufficient to fully compensate for the reduction in IR, there was an improvement in diet quality. The new season resumption of growth and germination of over-wintered seeds produced a significant increase in the CP content and reduction in the ADF and NDF contents of the herbage selected by the yaks (Table 2). The yaks extended their grazing time and increased the bites min^{-1} with the better forage quality (high CP content and herbage mass) (Tables 3 and 4). This agrees with the observations by Hancock (1954) and Fredrick (2002) that the quality of forage strongly influences feeding patterns in grazing animals. The live weight of yaks in May did not increase significantly compared with that in the previous 2 months, mostly because the herbage mass and the height of sward was low and the yaks had to expend more energy collecting food, but could not meet their daily nutrient intake requirement (Table 1).

The transitional and summer pastures were characterised by the new season's growth of herbage. On transitional pasture, the herbage mass was 522 kg DM ha^{-1}, significantly lower than that measured on the early spring pasture in March and April (1585 and 1544 kg DM ha^{-1}, respectively). Like the forages present on the late spring pasture (period 3), forages on the transitional and summer pastures had significantly higher CP contents and lower-fibre contents and than those of the senescent, early spring pasture. However, whereas the dominant pasture species contributing to the yaks' diet on the transitional pasture were the same as the late spring pasture (i.e. *C. qinghaiensis* and *K. pygmaea*), on the summer pasture they comprised *K. pygmaea* and *K. humlis* (Table 1). On the transitional pasture, the height of both dominant sedges, *C. qinghaiensis* and *K. pygmaea*, was slightly greater than in the late (period 3) spring pasture. This allowed the yaks to increase their DM bite mass from 0.46 to 0.80 g bite^{-1}, although the increase was not statistically significant. The increase in bite mass led to a significant reduction in bite rate on the transitional pasture compared with that on the late spring pasture, when measured over both the 1-h period of IR measurement and 24 h (Table 4). As a result of the increased bite mass but lower bite rate, DM IR did not differ significantly on the late spring and transitional pastures (proportionately 10% reduction from late spring to transitional pasture). As on the post-emergent spring pasture (period 3), TET on the transitional pasture was 529 min, significantly longer than in periods 1 and 2 on the spring pasture, although slightly shorter (by 114 min, $P > 0.05$) than that on the post-emergent spring pasture (Table 3).

During the period of behaviour measurements on the summer pasture, plants of *K. pygmaea* were slightly, though not significantly, taller than they had been on the transitional pasture (4.9 cm versus 3.7 cm), whereas plants of the co-dominant species *K. humlis* were of similar height (3.8 cm) (Table 1). The herbage mass was higher than that on the late spring (May) and transitional pastures (Table 1). Under these sward conditions, the bite masses achieved by yaks were proportionately about 0.5 of those on the transitional pasture (0.41 g versus 0.80 g, $P > 0.05$) and bite rates recorded during measurement of IR were increased from 31 to 41 bites min^{-1} (Table 4). However, this compensatory increase in bite rate was insufficient to maintain DM IR, which was low on the summer pasture (16.5 g DM min^{-1}) (Table 4). In response, compared with transitional pasture, yaks decreased their number of meals in an attempt to compensate for the reduced IR (Table 3).

During the period of measurement on the winter pasture, the height of the *C. qinghaiensis* plants was 7.5 cm, somewhat lower than during the spring (March and April). However, the herbage mass was 1429 kg DM ha^{-1}, significantly greater than in growing seasons of the year, excluding March and April (Table 1). Like in early spring pasture, the *C. qinghaiensis* in the winter pasture had low protein and high fibre contents: 43 g CP kg^{-1} DM, 297 g ADF kg^{-1} DM and 555 g NDF kg^{-1} DM (Table 2). Yaks significantly decreased TGT to less than 480 min on winter pasture because the dry matter intake rate was moderate (24.8 g min^{-1}) (Tables 3 and 4). Compared with on the transitional and summer pastures, yaks also decreased TET by approximately 2 h day^{-1}. On winter pasture, the live weight of yaks was 221 kg, significantly higher than that measured on spring and transitional pastures. Although, the quality of forage is poor on winter pasture, after grazing in transitional, summer and autumn pastures, yaks continue to gain weight on the early winter season.

Usually, yaks began ruminating after they had eaten herbage some time in the morning, which was also shown in Fig. 2. They generally ruminated at noon and night. Our personal observations showed they also ruminated when they were confined, e.g. milking. The finding that the act of rumination started only after the yaks had been at the pasture for some time is because a certain level of reticulo-rumen fill must be reached for an animal to start the process of rumination. The speed with which this level is attained depends on the rate of herbage consumption that is, in turn, influenced by herbage quality, quantity and degree of selectivity of the animals (Fredrick, 2002). Low quality or quantity forage is usually accompanied by a low DM IR, which consequently delays the onset of rumination (Mugerwa et al., 1973). The total ruminating time by yaks did not vary significantly on spring, transitional and winter pastures. On summer pasture, the total ruminating time was approximately 420 min, significantly higher than that measured on spring pasture (April and May), when it was approximately 240 min. The yaks could not meet their daily nutrient intake requirement because of the low quantity and quality (low CP and high ADF or NDF) of forages on spring pasture, so their ruminative activities were not consecutive (Fig. 2). However, because there was longer daylight and better sward conditions (high herbage mass and CP content) on summer pasture, the yaks grazed for longer than in dry periods (periods 1 and 2 of spring pasture, winter pasture) and then spent more time ruminating than in period 2 and period 3 of spring pasture. Compared with transitional and summer pastures, the yaks had the highest mastications per bolus in period 1 (March) of spring pasture and on winter pasture, which is related to the quality of herbage; the ADF content of *C. qinghaiensis* in period 1 of spring pasture and winter pasture was 321 and 297 g kg^{-1} DM, respectively, compared to 251 and 278 g kg^{-1} DM on transitional and summer pastures, respectively.

4.2. The effect of level of supplement on grazing and ruminating behaviour

In the present experiment, we observed that the yaks were able to consume their total ration within 10–15 min. Yak, like many other ruminants, have evolved a strong herding instinct, which they have retained, despite domestication. As a result, they exhibit an apparent awareness of their fellow herd members and a high level of behavioural synchronicity (Gerald et al., 2003). Thus, when most of the yaks did not eat the concentrates, others would do the same. When the concentrate ration was 0.5 or 1.0 kg per animal per day, the total grazing time or eating time decreased significantly ($P < 0.05$) compared with the unsupplemented yak. However, the total grazing time and eating time were lower when the concentrate ration was the 2.0 kg level than non-supplementation, but non-significant with statistical analysis. The reason needs further study. Total GJM on 0.5 and 1.0 kg supplements was significantly lower than on the 0 and 2.0 kg level of supplement. When the yaks were supplemented with concentrate pellets, the number of non-biting GJM was significantly lower than unsupplemented yak. After eating some concentrates, the yaks would reduce eating forage on the grassland, then the total GJM or non-biting GJM would decrease accordingly. However, the treatment did not significantly affect the BR. The less significant effect of concentrates on grazing behaviour may be due to the rapid digestion of the cereal-based concentrate following overnight rumination and evacuation (Gibb et al., 2002).

The level of supplementation had no significant effect ($P > 0.05$) on ruminating behaviour, either with respect to the time spent on rumination, the number of ruminative mastications and the number of mastications per bolus. This is in agreement with the observations on cows by Gibb et al. (2002) who thought this was due to the absence of any synergistic effects of the two dietary components (herbage and supplement) on ruminative requirements. Compared with herbage, the concentrates are easy to masticate and assimilate, so the yaks should not spend much time in masticating or ruminating after eating some concentrates.

5. Conclusion

The results show that yaks adapted their foraging behaviour in response to changes in sward conditions. In the dry periods or seasons, the yaks did not extend their grazing time because of the low quality of forage. In the germinating season (period 3 of spring pasture), the yaks increased their bite rate and TGT as a response to reduced bite mass. This research on yak foraging behaviour is a valuable aid to the improvement of the management of grazing livestock under alpine grassland on the Qinghai–Tibetan plateau, such as supplementation in dry seasons, decreasing stocking rate when the yaks have to spend much more time grazing, dispersing animals to improve their ability to make use of extensive pasture, or, according to the yak grazing behaviour, transferring animal herds or partitioning pasture.

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