Digestibility, nutrient balance and urinary purine derivative excretion in dry yak cows fed oat hay at different levels of intake

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Abstract

A feeding trial was conducted at the farm of Qinghai Academy of Animal and Veterinary Science, Xining, China during 1996–1997 with three dry yak cows (initial body weight 163–197 kg, age 5–6 years) by using 3 × 3 Latin Square Design to determine the effect of levels of feed intake on digestion, nitrogen balance and purine derivative excretion in urine of yak cows. The animals were fed oat hay (nitrogen 13.5 g/kg dry matter (DM), metabolisable energy 8.3 MJ/kg DM), i.e., 0.3, 0.6 and 0.9 of voluntary intake (VI). Each intake treatment lasted for 17 days and the samples (feeds, faeces and urine) were collected during last 7 days of each period. The results indicate that digestibility of dietary DM, OM, NDF and ash declined when intake levels increased from 0.3 to 0.9 VI [DM, from 66.1% to 59.1% (\textit{P}<0.05); OM, from 68.1% to 59.9% (\textit{P}<0.05); NDF, from 62.1% to 54.3% (\textit{P}<0.05); and ash, from 33.9% to 11.8% (\textit{P}<0.05)]. Around 0.10 g N/kg W\textsuperscript{0.75} was deficient daily in yak cows at 0.3 VI, and positive N balances were observed at 0.6 and 0.9 VI. Intake levels significantly (\textit{P}<0.05) affected total PD excretion in yak urine. The proportion of allantoin increased (\textit{P}<0.05) and uric acid decreased (\textit{P}<0.05) as intake level of feed increased.

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Keywords: Intake level; Digestion; Purine derivatives; Creatinine excretion; Dry yak cows

1. Introduction

Yaks (\textit{Bos ginnen}) are the characteristic and important grazing livestock on the Qinghai Tibetan Plateau. They provide milk, milk products (butter and milk residues), meat as the important food source and financial income, hair and hides as textile and leather materials, dung as the fuel for Tibetan herders, and are also used as pack and draught animals and for riding. However, yaks have to suffer from inadequate feeding in the long cold season (November to next June) due to herbage deficiency under pure grazing in the traditional farming system, which results in poor nutrition, health-related problems, low production and reduced fertility (Miller, 1996).

Supplementary feeds are required to quell the production decrease and high mortality in winter,
especially when grazing lands are covered by heavy snow (Guo and Chen, 1996; Long and Ma, 1996). Hay of cultivated forage, generally oat (*Avena sativa*) and straw of crops, such as oat and highland barley (*Hordeum vulgare*) have been used as the winter supplements by local farmers since China Reform of 1978 (Wu, 1996). However, limited amounts of oat hay are supplemented to the lactating and weak animals throughout winter or to the whole herd at snow disaster (Cai and Wiener, 1995), most animals are not given any supplements during the cold season on dry grassland (Long et al., 1999a).

Although supplementary regimes are very important to sustain yak farming systems in the cold season on the Qinghai-Tibetan Plateau, little information on performance of yak cows fed with different levels of supplementary feeds is substantially documented. The objectives of the current experiment were to establish the intake level of oat hay able to cover maintenance requirements of dry yak cows through analyzing the effect of level of feeding on the dietary digestibility, nutrients balance and urinary PD excretion in dry yak cows.

## 2. Materials and methods

The field experiments were carried out from October 1996 to July 1997 at Qinghai Academy of Animal and Veterinary Sciences, Xinning (36°8′ N, 101°37′ E, 3100 m a.s.l.). Three yak cows (initial body weight 163–197 kg, age 5–6 years) were selected randomly from the herd of dry animals and used in the experiment. During the experiment, the average air temperature was about 5 °C and the average relative humidity around 0.53.

### 2.1. Treatment

The yak cows were given oat hay ad libitum for 10 days to measure their voluntary intake (VI) after a 3-week recovery in normal pens from grazing. They were then given three levels of intake at 0.3, 0.6 and 0.9 VI in a 3 × 3 Latin Square Design in three 17-day periods. The oat hay contained (g/kg DM), respectively: organic matter (OM) 929.8, nitrogen 13.5, calcium 3.7, phosphorus 1.7, neutral detergent fibre (NDF) 674 and metabolisable energy (ME) 8.3 MJ/kg DM. Water was always freely available. The animals received their food allocation as two equal meals daily at 08.30 and 16.00, respectively. Samples of all offered and refused feeds were accumulated on a daily basis bulked to provide subsamples for chemical analysis.

The animals were housed individually in metabolism crates to facilitate faeces and urine collection. The total quantity of faeces voided daily by each cow was collected from a mesh every 2 h from 06:00 to 24:00 h in the last 7 days of each period and, after weighing, thoroughly mixed and a representative sample stored at −20 °C until required for chemical analysis. Daily urine was collected through the metal mesh by a plastic funnel into a plastic tray under the metabolism crate. To avoid contamination with faeces, the mesh was cleaned immediately after the faeces excretion and a tray was provided with the fine plastic mesh (2 mm) attached to the top edges. Daily excretion of urine was collected from each animal into a bucket during the last 7 days of each period. The buckets contained 10% (v/v) H₂SO₄ to ensure a final pH between 2 and 3 to avoid microbial growth. After weighing and thoroughly mixing, the subsamples were filtered and retained frozen. Subsequently, a representative sample was prepared for each cow in relation to individual daily outputs, and stored at −20 °C until required for N and PD analysis.

### 2.2. Chemical analysis

All the subsamples of feeds and faeces were dried at 60 °C for 48 h, ground to pass through a 1-mm screen and stored for chemical analysis. DM and ash contents of feeds and faeces were determined as described by A.O.A.C. (1990). Neutral detergent fibre (NDF) analysis was carried out according to Goering and Van Soest (1970). Analysis of total nitrogen of feeds and faeces was carried out using the Kjeldahl method as described by Davidson et al. (1970).

Subsamples of urine were analyzed for allantoin by high-performance liquid chromatography (HPLC) with pre-column derivation according to Chen et al. (1993) and for uric and hypoxanthine plus xanthine according to Chen et al. (1990a). In the latter method, hypoxanthine and xanthine were determined collec-
tively as uric acid after treatment with xanthine oxidase. Urine samples were diluted with distilled water before the assays, by 40 times for allantoin and 10 times for uric and hypoxanthine plus xanthine. N content of urine was determined by the method of Davidson et al. (1970). All daily urine samples were analyzed individually.

2.3. Statistical analysis

ANOVA were used to determine the effects of intake level on dry matter digestibilities of dietary dry matter (DMD), organic matter (OMD), ash and nitrogen, and concentrations of urine PD and N. All the analyses were achieved by using SPSS10.0 (Huang et al., 2001).

3. Results

3.1. Voluntary intake

As it is shown in Fig. 1, a linear ($P<0.05$) relationship between body weight of yak cows (W) and dry matter intake (DMI) of oat hay was obtained through a short feeding trial (10 days) on a small number of animals (three animals). Daily DMI of oat hay by yak cows can be estimated through equation, $\text{DMI (kg/day)} = 0.022 \text{ W (kg)} (R^2 = 0.76)$. The liner relationship between metabolic body weight of yak cows (W$^{0.75}$) and daily DMI of oat hay was also significant ($P<0.05$), following the equation, $\text{DMI (kg/day)} = 0.080 \text{ W}^{0.75} (kg) (R^2 = 0.72)$.

3.2. Dietary digestibilities

Daily intakes of DM, OM and digestibilities of DM, OM and NDF at different intake levels are presented in Table 1. The digestibility of DM, OM decreased ($P<0.05$) from 66.1% to 59.1%, 68.1% to 59.9% and 62.1% to 54.3%, respectively, when the intake level increased from 0.3 to 0.9 VI of oat hay.

![Fig. 1. Relationship between body weight of yak cow and daily dry matter intake.](image)

Table 1

Dietary digestibilities in yak cows at different intake levels

<table>
<thead>
<tr>
<th>Level of intake</th>
<th>S.E.M.</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.3 VI</td>
<td></td>
</tr>
<tr>
<td>0.6 VI</td>
<td></td>
</tr>
<tr>
<td>0.9 VI</td>
<td></td>
</tr>
<tr>
<td>Daily intakes</td>
<td></td>
</tr>
<tr>
<td>Dry matter intake (g/kg W$^{0.75}$)</td>
<td>27.03</td>
</tr>
<tr>
<td>Organic matter intake (g/kg W$^{0.75}$)</td>
<td>25.41a</td>
</tr>
<tr>
<td>Metabolic energy (kJ/kg W$^{0.75}$)</td>
<td>207.34a</td>
</tr>
<tr>
<td>Apparent digestibilities (%)</td>
<td></td>
</tr>
<tr>
<td>Dry matter</td>
<td>66.1a</td>
</tr>
<tr>
<td>Organic matter</td>
<td>68.1a</td>
</tr>
<tr>
<td>Neutral detergent fiber</td>
<td>62.1a</td>
</tr>
</tbody>
</table>

a, b, c, mean values with different letters within rows are significantly different ($P<0.05$).

Table 2

Daily nitrogen balance in yak cows at different intake levels

<table>
<thead>
<tr>
<th>Level of intake</th>
<th>S.E.M.</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.3 VI</td>
<td></td>
</tr>
<tr>
<td>0.6 VI</td>
<td></td>
</tr>
<tr>
<td>0.9 VI</td>
<td></td>
</tr>
<tr>
<td>Nitrogen intake (g/kg W$^{0.75}$)</td>
<td>0.34a</td>
</tr>
<tr>
<td>Excretion in faeces (g/kg W$^{0.75}$)</td>
<td>0.16a</td>
</tr>
<tr>
<td>Excretion in urine (g/kg W$^{0.75}$)</td>
<td>0.28a</td>
</tr>
<tr>
<td>Nitrogen balance (g/kg W$^{0.75}$)</td>
<td>-0.10a</td>
</tr>
</tbody>
</table>

a, b, c, mean values with different letters within rows are significantly different ($P<0.05$).
hay. The linear relationships with intake level were significant \( (P < 0.05) \).

### 3.3. Nitrogen balance

Table 2 shows the results of N balance in yak cows at different intake levels. N intake and N excretion in faeces increased linearly \( (P < 0.05) \) with the increased intake level. There was no clear trend of change in urinary N between different intake levels. Around 0.10 g N/kg \( W^{0.75} \) was deficient daily in yak cows when the animals were fed with 0.3 VI. Positive N balances were observed in yak cows when feeding levels increased to 0.6 and 0.9 VI.

### 3.4. Urinary purine derivatives excretion

Daily urinary PD excretion increased as intake level increased \( (P < 0.05) \) (Table 3). The relative proportions of the individual derivative varied with total PD excretion, the proportion of allantoin increased \( (P < 0.05) \) and uric acid decreased \( (P < 0.05) \) as total PD excretion increased.

### 4. Discussion

VI of oat hay by yak cows in this study was around 0.022 kg DM/kg \( W \), which is close to 0.024 kg DM/kg \( W \), the VI of oat hay obtained by Han et al. (1990) on several yak steers (10 animals, body weight 140–180 kg) in a long period of feeding trial (4 months). According to ARC (1980), the DMI of high quality grass hay by 100–200 kg cattle was 0.029 kg/kg \( W \). Xu (1986) reported that the DMI of high quality grass hay by Chinese cattle was 0.028–0.035 kg/kg \( W \). It can be preliminarily concluded that on per kilogram body weight basis the intake of roughages by yak is less than the cattle. The possible explanation is that yaks possess smaller rumen than the cattle, on their body weight basis (Liu et al., 1991). Yaks may have evolved from a long period of natural selection into smaller-rumen ruminants to survive feed-deficient season, i.e., long harsh winter (Han et al., 1990). According to Hu et al. (1992), maintenance requirement of energy (MEm) by dry yak cows or growing yak steers can be estimated as MEm (kJ) = 302 (kJ/kg) \( W^{0.75} \) (kg). On this basis, 0.45 VI of oat hay met the maintenance requirement by dry yak cows. Voluntary intakes of 0.9, 0.6 and 0.3 oat hay in the present study were equivalent to 2.1, 1.4 and 0.7 times requirement by dry yaks in terms of energy.

Decreased digestibility of feed with increased intake level in this study is consistent with the earlier findings that higher levels of intake of a particular roughage were associated with reduced digestibility (López et al., 2001) or high planes of feeding level led to low digestibility by ruminants (Bondi, 1987), due to the more rapid passage of digesta from the rumen (Balch and Campling, 1962; Chen et al., 1992a; Han et al., 1992), thus reducing the time available for ruminal microbial digestion (Owens and Goetsch, 1986). Although several researchers reported that the depression in OM (Hogan and Weston, 1971; Tamminga et al., 1979; Robinson et al., 1985) and fibre (Robinson et al., 1985) digestion caused by increased feed intake from near maintenance to ad libitum intake was not linear and greatest depressions in digestibility occurred at the highest levels of intake, the linear relationship between decreased digestibility of feed and increased intake level from below maintenance to near ad libitum intake was observed in this study. This difference may be highly related to the numbers of intake levels, which in the present study were only 3; non-linear effects on digestibility were difficult to detect by only using two or three levels of intake (Robinson et al., 1985).

Linear increase of N intake with increased feeding level can be easily understood because the yak cows ingested the same diet but different amounts. Increased excretion of N in faeces may be primarily due to significantly \( (P < 0.05) \) increased excretion of faeces with increased intake level, as no significant

<table>
<thead>
<tr>
<th>Level of intake</th>
<th>S.E.M.</th>
</tr>
</thead>
<tbody>
<tr>
<td>30% VI</td>
<td>60% VI</td>
</tr>
<tr>
<td>Allantoin (mmol/kg ( W^{0.75} ))</td>
<td>0.32a</td>
</tr>
<tr>
<td>Uric acid (mmol/kg ( W^{0.75} ))</td>
<td>0.07a</td>
</tr>
<tr>
<td>Total PD (mmol/kg ( W^{0.75} ))</td>
<td>0.39a</td>
</tr>
<tr>
<td>Allantoin/total PD</td>
<td>0.82a</td>
</tr>
<tr>
<td>Uric acid/total PD</td>
<td>0.18a</td>
</tr>
</tbody>
</table>

a, b, c, mean values with different letters within rows are significantly different \( (P < 0.05) \).
effect of intake level on N concentrations in faeces was observed in this study. It was reported that ruminal escape of bacterial N increased but rumen escape of feed N remained constant as feed intake level increased (Robinson et al., 1985). The higher excretion of N in faeces at higher intake levels in the present study may be attributed to the increased ruminal escape of bacterial N. It was found in a fasting trial that about 0.32 g/kg W^{0.75} endogenous N was excreted daily in dry yak cows (Long et al., 1999b), that’s why the animals fell into negative N balance when they were offered 0.34 g/kg W^{0.75} dietary N daily at the intake of 0.3 VI oat hay.

The difference in the daily PD excretion between different intake levels was probably due to the difference in the digestible organic matter intake (DOMI). A significant (P < 0.001) linear relationship between total PD excretion expressed in mmol/kg of metabolic weight (mmol/kg W^{0.75}) and DOMI expressed in g/kg of metabolic weight (g/kg W^{0.75}) was obtained by Long et al. (1999b). Similar to that for cattle (Verbic et al., 1990; Chen et al., 1992a) and buffaloes (Chen et al., 1996), xanthine and hypoxanthine were not detectable in the urine of yak. It was found in present study that the proportion of allantoin increased and that of uric acid decreased as total PD increased with increased intake level in dry yak cows. The similar results were previously obtained in sheep by other researchers (Chen et al., 1992b). The urinary excretion of purine derivatives by ruminants could be used as an index of microbial biomass and hence protein supply to the animal (Topps and Elliot, 1965; Rys et al., 1975; Chen et al., 1992b). However, some of the urinary purine derivatives originated directly from the animals’ tissues, and this endogenous contribution to the total excretion in urine had to be quantified (Chen et al., 1990b). Therefore, further study is needed to quantify the endogenous excretion of purine derivatives by yak, thus to establish a possible method for estimating intestinal microbial protein flow based on PD excretion in yak.

5. Conclusion

Dry yak cows can meet their maintenance requirement for energy and are in positive balance of nitrogen when fed with 0.6 VI of oat hay in winter season. It is suggested that yak cows should be fed or a minimum of 0.6 VI of oat hay to keep their health and maintain body weight in severe feed-deficient winter season, especially when heavy snow disaster occurs on the Qinghai-Tibetan Plateau.

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