Live-weight gain, apparent digestibility, and economic benefits of yaks fed different diets during winter on the Tibetan plateau

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Abstract

Our goal was to determine the effect of diets with different crude protein (CP) contents and metabolizable energy (ME) levels on daily live-weight gain, apparent digestibility, and economic benefit of feedlot yaks on the Tibetan plateau during winter. Yaks were either 2- or 3-years old and randomly selected from the same herd. The 3-year-olds were placed into one of two experimental groups (A and B) and a control (CK1), and the two-year-olds were placed into one of three experimental groups (C, D and E) and a control (CK2) (N per group=5). Yak in the control groups were allow graze freely, while those in the experimental groups yaks were fed diets higher in contains crude protein and metabolizable energy through a winter period inside a warming shed. Results indicated that live-weight gain of treatment groups was higher than their respective controls during experiment, and that daily live-weight gain of every 10 days among different treatments was significant difference (P<0.05). In addition, apparent digestibility of different diets was linearly and positively related to feedlotting time, and feed conversion efficiency for A, C, D and E groups was quadratically related to feedlotting time (P<0.01), however, feed conversion efficiency for B group was linearly and positively related to feedlotting time (P<0.05). The economic benefit was 1.15 for A, 1.89 for B, 1.16 for C, 1.54 for D, and 4.52 for E.

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Keywords: Yak; Daily live-weight gain; Apparent digestibility; Feed conversion efficiency; Yangtze and Yellow Rivers headwater region

1. Introduction

Yaks (Bos grunniens) play a crucial role in alpine meadow of the Qinghai-Tibetan plateau ecosystem and pastoral industry. In the Yangtze and Yellow rivers source region, there are approximately 3.3 million yaks, accounting for 23.77% of the world total (14 million), 25.38% of China’s total (13 million), and 73.33% of the total in Qinghai Province (4.5 million) (Miller, 1996). Yaks are primarily used for the production of milk, milk products, meat, hair and hides, and also as pack and draft animals and for...
riding. Yak dung is the fuel for the fires of Tibetan herders (Miller, 1996).

Because of the over stocking rates and irrational grazing systems, the yak has been caught in the vicious cycle of “gluttoning in summer, fatness in autumn, thinness in winter, weakness in spring” (Dong et al., 2003a). The ratio of herbage intake to live-weight gain is very high because of the imbalance in herbage supply, both in quantity and quality (Zhao et al., 1991). In the warm season (May to September), when the pasture develops from the green budding and exuberance phase to the withering phase, feed is plentiful and of good quality with high protein, fat, and non-structured carbohydrate content (Long et al., 1999a). During the cold season, yaks live mainly on standing dormant grasses and suffer from inadequate feeding in the long cold season, which lasts for more than 7 months (November to the following May) resulting in poor nutrition, health-related problems, reduced fertility, and the loss of 80% to 120% of live-weight gain from the warm season because of herbage deficiency under pure grazing in the traditional farming system (Miller, 1996; Long et al., 1999b). Consequently, the energy conversion of the traditional production system is very low (Zhao et al., 1989).

Sustaining livestock productivity is the main concern of most livestock production systems, including rangeland (Charudutt et al., 2001); however, pastoralists often maintain herds at a high stocking rate to maximize production, which can lead to rangeland degradation (Charudutt et al., 2001; Wang, 2003; Zhou et al., 2003). It is well-known that feed supplementation regimes is important in sustaining the yak farming system in the Yangtze and Yellow Rivers source region of the Qinghai-Tibetan plateau, but little information on the performance of growing yak fed with different energy and crude protein levels of supplements is available (Long et al., 1999b; Dong et al., 2003a,b, 2004a,c; De et al., 2004).

The objective of this study was to reduce decreased productivity and high mortality of yaks by providing supplements of different energy and protein levels in winter, and to determine the optimal diets and maximal benefits in this particular location. Ultimately, the goal of the study was to explore alternative ways to decrease gazing pressures on the natural grassland in the Yangtze and Yellow Rivers headwater region.

2. Materials and methods

2.1. Site description

The trial was conducted in the Dawu township (34°21′22″ N, 100°29′42″ E, 3980 m a.s.l.) of Maqin County, Guoluo Tibetan Autonomous Prefecture of Qinghai Province, China. The climate of the research area was dominated by southeast monsoon and high atmosphere pressure from Siberia, with severe, long winters and short, cool summers. The annual average air temperature was −2.3 °C with extremes of a 25.2 °C high and a −32.5 °C low, and without an absolute frost-free period. During the experiment, the average air temperature inside the warming shed was −16 °C, and outside it was −25 °C and the average relative humidity was around 0.52 inside and 0.49 outside.

2.2. Warming shed

The warming shed was (from east (front) to west (back)) 10 m in length, 6 m in width, 2.2 m in middle height, and 1.8 m along the south and north walls. Its front roof material was made of plastic, and the back roof was asbestos tiles. The shed had two doors (1.2 × 1.6 m) located on the south and north sides, and two windows (0.20 × 0.35 m) in the east and west walls, respectively. Inside the shed, there were some chamfers that were 65 cm in height, 30 cm in upper width, and 20 cm in bottom width near the wall. The shed also had a fenced area used as a “playground” for the yaks during daytime.

2.3. Elymus nutans and oat silage

Oat (Qinghai-444) sown on June 10, 2002, and harvested in early October 2002 was cut with a reaper, baled, and bound into round bundles with a weight of 50–60 kg. E. nutans grass was planted in early May 2002 and cut and bound into round bundles with a weight of 30–40 kg in mid-September 2003. The ratio of oat silage to dry grass was 2.8:1, and E. nutans silage to dry grass was 3.0:1.
2.4. Treatments and feeding regimes

Fifteen 3-year-old yaks with an initial live-weight of 120 ± 10 kg and twenty 2-year-old yaks with an initial live-weight 100 ± 10 kg were chosen randomly from the same herds. The 3-years-old yaks were allocated to two experimental groups (treatments A and B) and a control group (CK1) with 5 yaks per group. The 2-year-old yaks were divided into three experimental groups (treatments C, D, and E) and a control group (CK2), with 5 yaks per group. Yaks in the experimental groups received their special ration in two equal meals daily at 08:30 and 16:30, respectively. Yaks in control groups grazed in natural rangelands without any supplement. The rangelands consisted of alpine meadow dominated by *Kobresia parva* and *E. nutans*. Water was freely available during the experiment.

Feeding regimes included two broad categories: the starter ration and finisher ration. We took caution to reduce the stress of the experimental diets on the yaks. A starter ration was introduced in a series of five steps for the 3-year-old yaks and eight steps for 2-year-old yaks. The first gradation was a total roughage ration gradually replaced by grain until the desired concentration was obtained. The transition period of 14 days for the 3-year-old yak and 16 days for 2-year-old yak was introduced to ensure yaks did not develop digestive disorders. We kept the yaks on the *E. nutans* silage ration until all yaks were feeding. Likewise, yaks remained on the low-grain diet until all yaks had begun the high-grain and rapeseed-cake diet. The ration compositions, metabolizable energy (ME), and crude protein (CP) of each diet are listed in Table 1. Dietary composition was formulated based on nutrient requirements for CP and ME of growing yaks:

\[
ME_{(MJ/day)} = 0.458W^{0.75} + (8.732 + 0.091W) \times \Delta G, \text{ (concentrate diets)}; \\
ME_{(MJ/day)} = 1.393W^{0.52} + (8.732 + 0.091W) \times \Delta G, \text{ (rough diets) (Han et al., 1997a)}; \\
CP = 6.093W^{0.52} + (1.1548/\Delta W + 0.0509/W^{0.52})^{-1}, \text{ where } 6.093W^{0.52} \text{ is maintenance of } N, \text{ and } (1.1548/\Delta W + 0.0509/W^{0.52})^{-1} \text{ is required } N \text{ of live-weight gain (Xue et al., 1997).}
\]

2.5. Sample collection and yak weighing

The feedlot experiment was conducted from Nov. 14, 2002 to Jan. 24, 2003 for the 3-year-old yaks, and from Nov. 8, 2003 to Jan. 7, 2004 for the 2-year-old yaks. During the experiment, samples of the offered and refused feeds were accumulated on a daily basis and bulked to provide subsamples. The total quantity of feces voided daily by each yak was collected during each period (10 days) and was weighed with a special electronic balance and thoroughly mixed, before a representative sample was taken and stored. Yaks were weighed every 10 days during experiment with an animal electronic balance. All subsamples of feeds were dried at 60 °C for 24 h, and feces were dried at 60 °C for 48 h.

2.6. Statistical analysis

ANOVA was used to determine the effects of different diets and feedlot time on daily live-weight gain and digestibility. Differences in live-weight gains and the economic benefits among the different treatments were analyzed using *t*-tests. Regressions were determined by trend line of figure with KGraph (KaleidaGraph 3.5) software.

3. Results

3.1. Growth performance

Daily live-weight gain of every 10 days for different treatment groups over the experimental period was presented in Fig. 1. The data indicated
that there were significant differences \((P<0.05)\) among daily live-weight gains under the same feedlotting time for different treatment groups over experimental periods (Fig. 1). All treatment groups either in 2-years-old yak groups or in 3-years-old yak groups showed the daily live-weight gain in higher CP and ME was much better \((P<0.05)\).

3.2. Dietary digestibility

Digestibility (apparent digestibility) is ratio of \("(voluntary intake – feces)/voluntary intake"\) (all were dry matter). A linear relationship between digestibility and feedlotting time was found in the study \((P<0.05)\). The linear equations for each treatment are presented in Fig. 2. Their correlation coefficients \((R)\) were 0.89 for A, 0.82 for B, 0.86 for C, 0.83 for D, and 0.85 for E.

3.3. Live-weight gain and feed utilization

Feed utilization as measured by feed conversion efficiency (voluntary intake/live-weight gain) is an important index that reflects on digestion efficiency and absorption in livestock (Zaman et al., 2002). Feed conversion efficiencies of diets for different treatments in relation to feedlotting time are presented in Fig. 3. Feed conversion efficiency was quadradically related to feedlotting time. From these regressive equations, we calculated the time to achieve minimum feed conversion efficiency of the diets for each group was: 25 days for A, 27 days for C, 38 days for D, and 7 days for E, and their minimum values were: 11.11, 8.29, 9.91 and 9.05, respectively.

With the decrease in ME and CP contents in the diets, absolute and relative live-weight gain (live-
weight gains during experiment amount to percentage of initial live-weight) of either 2-years-old yak groups or 3-years-old yak groups decreased. Table 2 shows the effects of ME and CP contents on live-weight gain of the experimental and control group yaks before and after the experiment. Live-weight gain of different experimental groups was 22.64 kg/head for A, 16.74 kg/head for B, 13.62 kg/head for C, 12.14 kg/head for D, and 9.98 kg/head for E, which amounted to 19.19%, 14.25%, 12.27%, 10.83%, and 8.86% of their initial live-weight, respectively. The CK1 and CK2 groups decreased by 8.80 and 6.81 kg/head, respectively, which amounted to 7.40% and 6.16% of their initial live-weight, respectively. Supplement diet treatment significantly affected live-weight gain of yaks compared to the control group (P < 0.05). Furthermore, the higher the proportion of concentrate, the higher the feed conversion efficiency of the diets (total voluntary intakes to total live-weight gains), and feed conversion efficiency were higher in the 3-year-old yaks than in the 2-year-old yaks.

3.4. Economic benefit

The beneficial return from the experimental yak groups was based on the following equation:

\[
\text{Output } (O)/\text{input } (I) = \frac{\text{LWG} \times \text{MPY}}{(\text{ET} \times \text{DI} \times \text{MPF})}
\]

where LWG is the live-weight gain (kg/head), MPY is the market price of yak-beef (¥/kg), ET is experiment time (day), DI is the daily intake (kg/head day), and MPF is the market price of feeds (¥/kg).

The cost of different feeding regimes, live-weight gain, and economic data are shown in Table 3. Profits for the different experimental groups were 20.60 ¥/head for A, 55.07 ¥/head for B, 12.46 ¥/head for C, 29.86 ¥/head for D, and 54.39 ¥/head for E (P < 0.05). Profits of A and B groups were 82.2 ¥/head and 116.67 ¥/head higher than ones of the CK1 group, respectively, and which of C, D, and E groups were 60.13 ¥/head, 77.53 ¥/head, and 102.06 ¥/head higher, than ones of the CK2 group (P < 0.05), respectively. In addition, their economic benefits were

Table 2
Changes of absolute and relative live-weight of 3-year yaks (A, B and CK1 group, n = 5) and 2-year yaks (C, D, E and CK2 group, n = 5) under the different treatments during experiment (50 days) (mean ± S.E.).

<table>
<thead>
<tr>
<th>Treatment groups</th>
<th>Live-weight of adaptive starter (kg)</th>
<th>Live-weight of feedlotting finisher (kg)</th>
<th>Absolute live-weight change (kg/head)</th>
<th>Relative live-weight change (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>118.0 ± 6.78</td>
<td>140.6 ± 19.65</td>
<td>22.6 ± 6.45a</td>
<td>19.2 ± 7.12a</td>
</tr>
<tr>
<td>B</td>
<td>117.5 ± 7.02</td>
<td>134.2 ± 16.85</td>
<td>16.7 ± 5.12a</td>
<td>14.3 ± 3.21a</td>
</tr>
<tr>
<td>CK1</td>
<td>118.6 ± 8.21</td>
<td>109.8 ± 10.10</td>
<td>-8.8 ± 1.99b</td>
<td>-7.4 ± 2.02b</td>
</tr>
<tr>
<td>C</td>
<td>109.5 ± 32.30</td>
<td>124.6 ± 19.98</td>
<td>13.6 ± 3.30a</td>
<td>12.3 ± 2.09a</td>
</tr>
<tr>
<td>D</td>
<td>110.4 ± 27.91</td>
<td>124.2 ± 23.91</td>
<td>12.1 ± 1.98a</td>
<td>10.8 ± 2.16a</td>
</tr>
<tr>
<td>E</td>
<td>110.9 ± 23.91</td>
<td>122.6 ± 22.89</td>
<td>10.0 ± 1.01a</td>
<td>8.9 ± 2.21a</td>
</tr>
<tr>
<td>CK2</td>
<td>110.5 ± 21.90</td>
<td>103.7 ± 213.71</td>
<td>-6.81 ± 2.12b</td>
<td>-6.2 ± 1.99b</td>
</tr>
</tbody>
</table>

* Means within columns with different symbols (a, b) are significantly different (P < 0.05).

Table 3
Economic benefit of feedlotting yaks under different diets*

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Dietary cost (¥/kg)</th>
<th>Voluntary intake (kg/head)</th>
<th>Cost per kg live-weight gain (¥/kg)</th>
<th>Profit (¥/head)</th>
<th>Profit over CK (¥/head)</th>
<th>Economic benefit (output:input)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>0.79</td>
<td>174.0 ± 13.12</td>
<td>6.07</td>
<td>20.60a</td>
<td>82.20</td>
<td>1.15a</td>
</tr>
<tr>
<td>B</td>
<td>0.49</td>
<td>125.3 ± 11.20</td>
<td>3.71</td>
<td>55.07b</td>
<td>116.67</td>
<td>1.89b</td>
</tr>
<tr>
<td>CK1</td>
<td>0.72</td>
<td>114.2 ± 9.98</td>
<td>6.06</td>
<td>-61.60c</td>
<td></td>
<td></td>
</tr>
<tr>
<td>C</td>
<td>0.54</td>
<td>101.6 ± 10.99</td>
<td>4.54</td>
<td>12.46a</td>
<td>60.13</td>
<td>1.16a</td>
</tr>
<tr>
<td>D</td>
<td>0.20</td>
<td>77.0 ± 6.89</td>
<td>1.55</td>
<td>29.86a</td>
<td>77.53</td>
<td>1.54b</td>
</tr>
<tr>
<td>E</td>
<td>0.20</td>
<td>0</td>
<td>-47.67c</td>
<td>54.39b</td>
<td>102.06</td>
<td>4.52c</td>
</tr>
</tbody>
</table>

*Means within columns with different symbols (a, b, c) in the same experiment are significantly different (P < 0.05).
1.15, 1.89, 1.16, 1.54 and 4.52 for A, B, C, D and E group, respectively ($P<0.05$).

4. Discussion

Under the traditional farming system, yaks suffer from inadequate feeding during winter in the Yangtze and Yellow rivers source region of the Qinghai-Tibetan plateau, where more than 90% of grassland is overstocked in cool-season pastures, and in addition of CP content of pasture decreased from 11.4% in the warm-season pasture to 6.21% (Miller, 1996; Zhao et al., 2000). In the warming-shed feeding regime, although yaks were fed on starter rations for 14 to 16 days before the experiment began, rumen microorganisms did not thoroughly adapt to the finishing ration; the higher the CP content and ME levels, the longer the time required to adapt to a new ration (Ørskov and Ryle, 1990; Ørskov, 1992; Hao et al., 2000; Dong et al., 2003b, 2004a,b,c). In the current study of daily live-weight gain and feed conversion efficiency of yaks were affected by CP content and ME levels, and apparent digestibility was positively and linearly related to feedlotting time, which are similar to findings by other researchers for on-feedlot beef with oats and barley (McAllister et al., 1998; Fernandez and Woodward, 1999; Woodward and Fernandez, 1999; Zaman et al., 2002), and for feedlot yak and lamb with oats (Wang et al., 1997; Yu et al., 1997; Dong et al., 2003b; Long et al., 2004). During the current experiment, the time required for dietary conversion efficiency to reach the maximum differed for different age groups. Three-year-old yaks adapted more quickly to the diets with high CP content and ME levels than did the 2-year-old yaks. Moreover, Hao et al. (2000) and Ørskov and Ryle (1990), Ørskov (1992) reported that the time for rumen microorganisms to adapt to new diets is about 3 months. In our study, apparent digestibility of diets for experimental yaks gradually increased with feedlotting time during an experiment of 50 days’ duration.

Apparent digestibility in growing yaks decreased with increased CP content and ME levels during the early stages in this study because rumen environments did not adapt to new diets. This finding is consistent with earlier findings that higher levels of intake of a particular roughage were associated with reduced digestibility (Dong et al., 1997, 2003b; Long et al., 2004) or that high feeding levels led to low digestibility by ruminants because of the more rapid passage of digesta from the rumen (Ørskov and Ryle, 1990; Ørskov, 1992; Han et al., 1992; Hao et al., 2000; Long et al., 2004) in yaks. These yak findings also reflect results in cattle and water buffalo (Levy et al., 1986; Jewell and Campling, 1986; Rule et al., 1986; Huhtanen, 1988; Elizalde et al., 1996; Hussain and Cheeke, 1996; Mulligan et al., 2002; Shane Gadberry et al., 2005), and indicate a reduction in the time available for rumen fermentation and intestinal digestion (Han et al., 1997b; Liu et al., 1997; Xue and Han, 1997). As the experiment progressed, however, new rumen microorganisms adapted gradually to high-CP and -ME diets; thus, apparent digestibility continually increased during the study. Furthermore, apparent digestibilities (50–69%) of different diets for growing yak in this study were lower than those identified in growing yak by other researchers (60–77%) (Xue and Han, 1997) and approaches that of full-grown yaks (Long et al., 2004). In full-grown ruminants, rumen condition reaches microorganism equilibrium and cannot adapt to high-grain and rape-cake as quickly as can the rumen of growing ruminants including yaks (Ørskov, 1992; Tian et al., 1997; Hao et al., 2000; Dong et al., 2003b).

Daily live-weight gain of every 10 days for different treatment groups over the experimental period were significant differences ($P<0.05$) (Fig. 1). And total gain over experiment for treatments both 2- and 3-year-old yaks was higher than control yaks ($P<0.05$) (Table 2). All treatment groups both in 2-year-old yak groups and in 3-year-old yak groups showed the daily live-weight gain in higher CP and ME was much better ($P<0.05$), which agrees with Dong et al. (2004a,b,c) in yak. Similar results were also found in cattle and water buffalo (Hussain and Cheeke, 1996; Mulligan et al., 2002; Shane Gadberry et al., 2005). Although the influence of different diets and CP and ME levels on digestibility and daily gain in other ruminants is well documented (Jewell and Campling, 1986; Huhtanen, 1988; Hussain and Cheeke, 1996; Mulligan et al., 2002; Mani and Chandra, 2003; Silva et al., 2004; Abdelhadi et al., 2005; Shane Gadberry et al., 2005), relevant data in yak are sparse (Long et al., 2004, 2005; Dong et al., 2004a,b). Therefore, further study is needed to measure
dietary apparent and real digestibility of different CP contents and ME levels and to quantify the maintenance requirement of different diets for growing yak.

In addition, feed conversion efficiency as measured economically was negatively related to CP content and ME levels during the experiment, which agreed the results of Liu et al. (1997) and Xue et al. (1997), but was lower than the results of Dong et al. (2000, 2003b). In other words, feed conversion efficiencies are inversely correlated with CP content and ME levels, which was similar to the efficiency of legume straws mixed with concentrates (Wang et al., 1997; Xue et al., 1997) and oat silage mixed with concentrates (Dong et al., 2003b, 2004a,c).

Table 3 also lists the economic benefit (input/output) ratios for the A and C groups as 1.15:1 and 1.16:1, however, and their live-weight gains are higher than any other groups in the same-age groups, and the economic benefits for the two groups are lower than any other groups for the same-age yaks. The economic benefit for B and D groups are 1.89:1 and 1.54:1, respectively, which supports the assumption that when moderate concentrates were supplied to the 2- and 3-year-old yaks, a reasonable economic benefit is expected. The E group showed the best economic benefit with an output/input of 4.52:1 because of its lowest feeding cost. As for A and C groups fed high concentrates, the economic benefits of feeding were relatively low, and it was difficult for herders to accept and use; however, for the B and D groups, middle concentrates were comparatively acceptable, and other researchers have obtained similar results (Dong et al., 2003a; De et al., 2004; Long et al., 2005). The beneficial return of E (100% silage) was higher than the 4.07:1 and 3.5:1, as reported by Xue et al. (1997) and Zhang (1998), respectively.

5. Conclusion

All treatment groups both in 2-year-old yak groups and in 3-year-old yak groups showed the daily live-weight gain in higher CP and ME was much better. Relationships between feed conversion efficiency and feedlotting time are quadratic regression except for B group; however, apparent digestibility of different diets for 2- and 3-year-old yaks is linearly and positively related to the feedlotting time. Three-year-old yaks can adapt to high CP and ME diets better and attain more benefits with the same diets than can 2-year-old yaks. Mid-concentrates mixed with silage or hay could be extended and widely accepted by local Tibetan farmers in the Yangtze and Yellow Rivers source region of the Qinghai-Tibetan plateau as far as economic benefits are concerned.

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