Seasonal changes in weight and body composition of yak grazing on alpine-meadow grassland in the Qinghai-Tibetan plateau of China[1]

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ABSTRACT: Forty-five male yaks (born April 2001) were studied to determine how seasonal changes on the Qinghai-Tibetan plateau affected BW and body composition. Thirty yaks were weighed monthly from birth to 26 mo of age to determine seasonal changes in BW. The remaining 15 yaks were allocated randomly to five groups (three yaks per group), designated for slaughter at 13, 15, 18, 22, and 25 mo to measure seasonal effects on body chemical composition. All yaks were grazed on the alpine-meadow grassland of the plateau without any supplementation. All BW and body composition data were calculated on an individual basis. Body weight and body composition data were both compared across seven growth periods spanning 2 yr and defined by season. From April (birth) to December 2001 of the first growing season, yak BW increased ($P < 0.01$); however, during the subsequent cold season (December 2001 to May 2002), BW decreased ($P < 0.01$). The second growing season ran from May 2002 (13 mo of age) to October 2002 (18 mo of age), and the second live weight-loss season ran from October 2002 until May 2003. The weight loss experienced by yaks during the first weight-loss season was 25.64% of the total weight gain in the first growing season. The weight loss experienced by yaks during the second weight-loss season was 29.73% of the total weight gain in the second growing season. Energy retention in the second growing season was 291.07 MJ, 50.8% of which was consumed during the subsequent cold season. Energy accumulation in the summer (from May to July) and fall (from July to October) of the second growing season did not differ (5.01 and 6.30 MJ/kg of EBW gain, respectively; $P = 0.63$). The energy mobilized during the second winter (from October 2002 to February 2003) was 16.49 MJ/kg of EBW, and in the second spring (from February to May 2003), it was 9.06 MJ/kg of EBW. These data suggest that the decrease in grazing yak BW during the first cold season is much less than during the second cold season, and that the energy content per unit of BW mobilized is greater ($P = 0.02$) in winter than in spring. Results from this study demonstrate highly efficient compensatory growth in grazing yaks following the first weight loss period during the first cold season. This benefit could be exploited by herders to improve yak production. Yaks may have developed a type of self-protection mechanism to overcome the long cold seasons in the Qinghai-Tibetan plateau.

Key Words: Body Composition, Body Weight, Grassland, Live Weight, Seasonal Dynamics, Yak

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Introduction

The Qinghai-Tibetan plateau contains a substantial portion of the world's alpine-meadow rangeland, extending over 130 million ha (Long et al., 1999b). This rangeland supports nearly 41 million Tibetan sheep and 13 million yaks (Long et al., 1999b). The alpine-meadow rangelands of the plateau are characterized by low temperature and high altitude, and their high temporal variability in temperature and precipitation directly affects plant productivity. Frigid weather conditions shorten the growth period of vegetation to approximately 100 to 150 d, and prolong the dormant period to almost 7 mo. Grasses germinate at the beginning of May, with peak biomass occurring between late August and early September (Zhao et al., 2000). During the vegetative growth season from May to September, there is an increased forage supply, which would be expected to increase yak BW. As the forage supply decreases in winter, yak BW decreases (Long et al., 1999a), and some yaks cannot survive the extended shortage of forage supply. Losses of up to 30% of the yak population have been reported

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Table 1. Seasonal climatic data in Su-nan County[a]

	Spring April to May	Summer May to July	Autumn July to October	Winter October to April
Temperature, °C	3.8	14.5	8.6	–10.5
Solar radiation, MJ/m^2	682.6	899.0	874.5	—
Precipitation, mm	43.1	111.6	96.4	2.6

[a]Source: Su-nan Weather Station, 1952 to 1980.

in extremely cold years (Long et al., 1999a). This has resulted in a centuries' old grassland yak production cycle, where the yak is expected to satiate in summer, fatten in fall, become thin in winter, and die in spring on the Qinghai-Tibetan plateau. The effect of this cycle is low growth efficiency and low production efficiency for the grassland production system of this plateau, where the standard for marketing and slaughtering of yaks is 5 yr of age or older. Existing information documenting seasonal changes in yak BW and body composition is limited. The objective of this research was to elucidate seasonal effects on the BW and body composition of yaks grazing on the alpine-meadow grasslands of the Qinghai-Tibetan plateau.

Materials and Methods

Experimental Site

This study was conducted on the Su-nan Deer Farm, situated in an alpine-meadow grassland north of Qilian Mountain, Gansu province, at lat 38°87′ N, long 99°65′ E. The altitude of the grassland ranges from 2,600 to 2,900 m. Most of the annual rainfall of about 253.7 mm falls during the warm, wet season from May/June to October. Average annual temperature is 3.6°C, with a low temperature of –18.4°C in January, and a high temperature of 13.9°C in July. During the vegetative growing season from May to September, the total sunshine, total solar radiation, and total physiology radiation is 1,143.7 h, 62.2 kcal/cm^2, and 30.3 kcal/cm^2, respectively. Climatic information for each season is shown in Table 1. The dominant species of grassland communities are *Stipa krylovii, Stipa breviflora, Stipa grandis, Agropyron J., Leymus secalinus, Poa indattenuata, Elymus nutans, Artemisia frigida Willd, Heteropappus altaicus* (Willd.) *Novopokr, Oxytropis glabra* DC., *Caragana Fabr., Melilotoides, Polygonum viviparum* L., *Carex kansuensis Nelmes, kobresia capillifolia* (decne.), *C. B. Clarke, and kobresia humilis* (C. A. Mey.) *Serg.*

Experimental Animals

Throughout the period of study, all yaks grazed on the native grasslands in the Su-nan Deer Farm. Forty-five male yaks were allocated at birth to a live (n = 30) or slaughter (n = 15) experimental group. Male calves were born in spring (April 2001) and weaned in the fall (August to September 2001). Their average initial BW was 11.5 kg (SD = 0.70), which did not differ between the groups ($P = 0.92$). In the live experiment group (n = 30), yaks were weighed monthly for 26 consecutive months from birth to June 2003 to document seasonal fluctuations in BW. The slaughter group was subdivided into five groups of three yaks, each used to determine the seasonal effects on chemical body composition and whole-body energy dynamics. The identification of study intervals by month, age, and season is presented in Table 2.

Body Composition Determination

Fifteen yaks were randomly divided into five groups (three yaks per group) designated to be slaughtered at 13, 15, 18, 22, and 25 mo of age. Before slaughter, yaks were fasted for 24 h. At slaughter, yaks were exsanguinated, and blood was collected. Yaks were then eviscerated, and the digestive tract contents removed. The head, hooves, blood, hide, internal organs, alimentary tract, and carcass were weighed separately. The carcass was further separated into meat and bone, and these two components were weighed separately. The fat from the carcass and from the internal organs were defined as the carcass and internal organ components, respectively. Empty body weight (**EBW**) was considered the sum of the weight of the carcass, the empty gastrointestinal tract (**GIT**), other noncarcass components, and the blood. The weight of gut contents was determined to be the difference between BW and EBW.

Sampling

Blood, skin, meat, and bone were sampled separately. The internal organs and alimentary tract were ground into a homogeneous mixture in a meat grinder (Shuanghuan DJQ-B, Chongqing, China) to obtain a homoge-

Table 2. The division of different growth periods by age and season

Item	Age	Season
April (birth) to December 2001	0 to 8 mo	Four seasons
December 2001 to February 2002	8 to 10 mo	Winter
February to May 2002	10 to 13 mo	Spring
May to July 2002	13 to 15 mo	Summer
July to October 2002	15 to 18 mo	Fall
October 2002 to February 2003	18 to 22 mo	Winter
February to May 2003	22 to 25 mo	Spring

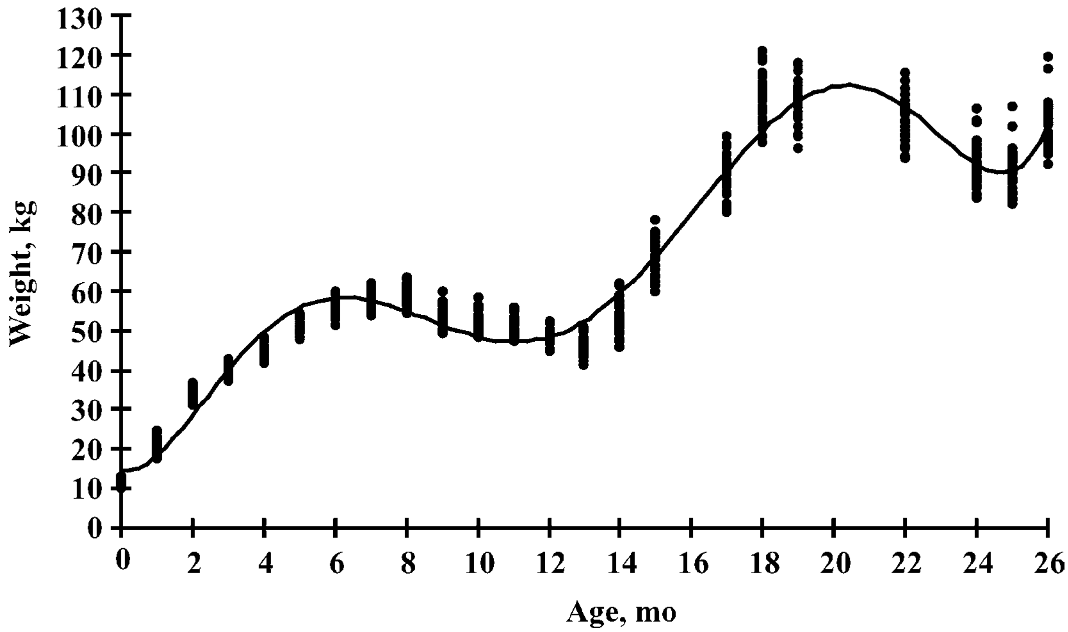

Figure 1. Body weight fluctuation of yak grazed on natural grassland in Su-nan.

nized sample. All samples (200 to 300 g) were subject to chemical analysis for CP, crude fat, DM, and energy content. Dry matter was determined by oven-drying at 105°C for 20 h. Crude protein and GE were determined on duplicate samples using Kjeldahl procedures (COM-04A Kjeldahl; Shibo Biotechnology Co., Shanghai, China) and a bomb calorimeter (model 1720; Parr Instrument, Moline, IL), respectively. Crude fat and CP were determined according to AOAC (1984) standard procedures.

Calculations and Statistical Analyses

All BW and body composition data were calculated on an individual basis. Crude protein was calculated as N × 6.25, and water as 100 minus %DM. Yak BW data and body composition data were compared across growth periods using the GLM procedure of SAS (SAS Inst., Inc., Cary, NC). Growing period was the dependent variable. The significance level was 0.05, and means were separated using the LSD procedure.

Results and Discussion

Seasonal Fluctuations in Grazing Yak BW

Seasonal fluctuations in grazing yak BW is illustrated in Figure 1. From birth to December 2001 (0 to 8 mo of age), yak BW was increased ($P < 0.01$) compared with the first cold season (December 2001 to May 2002; 8 to 13 mo of age), during which time, BW decreased. Body weight increased ($P < 0.01$) during the second growing season (May to October 2002; 13 to 18 mo of age); however, during the second cold season (October 2002 to May 2003; 18 to 25 mo of age), BW loss began 2 mo earlier ($P < 0.01$) than BW loss during the first cold season following birth. This difference may be a result of the 3- to 4-mo suckling phase in the first year growth period, which delayed the beginning of BW loss.

Seasonal fluctuations in BW are summarized in Table 3. Changes in BW differed ($P < 0.01$) among the seasons, excluding the difference between the first winter (December 2001 to February 2002) and the first spring (February to May 2002) of the first cold season (6.5 vs. 5.6 kg, respectively; $P = 0.10$). The BW losses during the first winter (December 2001 to February 2002) and the first spring (February to May 2002) accounted for 13.8 and 11.9%, respectively, of the total weight gain (47.2 kg) from birth to December 2001. Therefore, as much as 25.7% of the total BW gained during the first growth season was lost during the first cold season. The second growth season (May to October 2002) was characterized by a BW gain of 22.2 kg in summer (May to July 2002) and 40.8 kg in fall (July to October 2002), respectively. Of this total gain of 63.0 kg, 6.1 and 12.7 kg were lost during the subsequent winter (October 2002 to February 2003) and spring (February to May 2003), respectively. The BW losses in the second winter (October 2002 to February 2003) and the second spring (February to May 2003) accounted for 9.7 and 20.2%, respectively, of the total BW gain in the second summer (May to July 2002) and the second fall (July to October 2002). Therefore, as much as 29.9% of total BW gained during the second growth season was lost during the second cold season.

Daily BW gain was greater ($P < 0.01$) in the second fall (July to October 2002) than in the second summer (May to July 2002), and daily BW loss was greater ($P < 0.01$) in the second spring (February to May 2003) than in the second winter (October 2002 to February 2003). There was no difference ($P = 0.12$) in daily BW loss

Table 3. Seasonal effects on BW change (BWC) and ADG of 1- to 2-yr-old yak in Su-nan

Item	April to December 2001	December 2001 to February 2002	February to May 2002	May to July 2002	July to October 2002	October 2002 to February 2003	February to May 2003	SEM
BWC, kg	47.2[a]	–6.5[b]	–5.6b[c]	22.2[d]	40.8[e]	–6.1[bf]	–12.7[g]	1.464
ADG, kg	0.197[a]	–0.108[b]	–0.094[bc]	0.247[d]	0.680[e]	–0.068[f]	–0.141[g]	0.019

[a,b,c,d,e,f,g]Means within a row that do not have a common superscript differ, $P < 0.05$.

between the first winter (December 2001 to February 2002) and the first spring (February to May 2002). These results indicate that BW gain in yaks occurs primarily in the fall, and BW loss is more likely in spring. Yak growth is therefore not constant (Table 3), and the seasonal influences on growth limit the efficiency of yak production when yaks are typically marketed at 5 yr of age.

Compensatory Growth

The growth rate of yak generally is not constant from birth to slaughter, especially on the Qinghai-Tibetan plateau where the annual nutrient supply of grassland varies greatly with the season. In the first year of the spring-born yak in Su-nan County, the BW increased steadily until the first cold season (Figure 1 and Table 3). From January through May (winter through spring), BW decreased due to the severe cold of the winter/spring season, which produced temperatures that fell below yak thermoneutrality, as well as a shortage of forage supply in spring. From May through October (summer through fall), BW again increased. The ADG by our grazing yak during this warm season was 0.42 kg/d, compared with the 0.25 kg/d reported by Xue et al. (1994) for feedlot yak (weighed in morning before feeding) fed a high-concentrate diet. Thus, our grazing yaks showed highly efficient compensatory growth relative to feedlot yak.

Compensatory growth is the term coined by Bohman (1955) to describe the accelerated or more efficient growth that commonly follows a period of growth restriction. The effects of a previous plane of nutrition on subsequent growth of domestic livestock have been documented extensively (Wilson and Osbourn, 1960; Allden, 1970; Moran and Holmes, 1978). The phenomenon of compensatory growth is of considerable practical significance to grassland livestock production. The efficacy of compensatory growth in a segmented production system is based on the differences in market value and growth efficiency between compensating and noncompensating animals. In an integrated yak production system such as that on the Qinghai-Tibetan plateau, actual input costs for each phase of production should be considered. Our data documenting the BW loss in grazing yak in the cold season demonstrated that the decrease in BW during the first weight-loss season consumed 25.7% of the total BW accumulation of the first (preceding) growing season, and that BW loss during the second weight-loss season consumed 29.9% of total BW accumulation during the second growing season.

Although daily BW loss did not differ ($P = 0.46$) between the first (–0.101 kg/d) and second cold seasons (–0.104 kg/d), total BW loss was greater ($P < 0.01$) in the second cold season (–18.8 kg) than in the first (–12.1 kg). This difference, however, was primarily due to a longer second cold/weight-loss season of 7 mo (November to May) compared with 5 mo (January to May) for the cold season following birth. Therefore, a prolonged period of growth suppression seems to have no benefit for either the economic income of the herders or the efficient utilization of the natural resource. Herders could instead exploit the compensatory growth of 1-yr-old yaks following the first weight-loss season, and rear yaks to 18 mo for market or slaughter. In most countries, cattle typically are slaughtered at weights substantially less than mature weight (Owens et al., 1995).

Table 4. Physical composition (%) of empty body weight (kg) of grazing yak in Su-nan

Item	13 mo	15 mo	18 mo	22 mo	25 mo	SEM
EBW[a]	38.3[e]	54.8[f]	87.6[g]	83.6[gh]	74.4[i]	2.900
GF[b]	8.2[e]	14.0[f]	21.5[g]	20.0[gh]	16.1[fi]	1.113
Head	3.10[e]	4.52[f]	6.90[g]	6.62[gh]	5.98[i]	0.227
Hooves	1.49[e]	2.17[f]	3.38[g]	2.85[h]	2.28[fi]	0.118
IO[c]	1.82[e]	2.72[f]	4.28[g]	4.22[gh]	3.73[i]	0.167
GIT[d]	3.13[e]	4.83[f]	7.58[g]	6.85[h]	5.60[i]	0.243
Blood	2.62[e]	3.92[f]	6.37[g]	5.22[h]	4.37[fi]	0.201
Hide	3.25[e]	4.73[f]	7.52[g]	6.78[gh]	6.10[hi]	0.303

[a]EBW = empty body weight.
[b]GF = gut fill.
[c]IO = internal organ.
[d]GIT = gastrointestinal tract.
[e,f,g,h,i]Means were separated if the main effect of month was significant; therefore, within a row, means that do not have a common superscript differ, $P < 0.05$.

Table 5. Body weight gain (BWG) and gut fill gain (GFG) by season in Su-nan

Period	May to July 2002	July to October 2002	October 2002 to February 2003	February to May 2003	SEM
BWG, kg	22.3[a]	40.7[b]	–5.9[c]	–13.1[c]	6.69
GFG, kg	5.8[a]	7.5[a]	–1.5[b]	–3.9[b]	1.571
GFG/BWG	0.260	0.184	0.254	0.298	—

[a,b,c]Means within a row that do not have a common superscript differ, $P < 0.05$.

Physical Composition of Grazing Yak

Gut fill represents the difference between EBW and BW. Gut fill accounts for about 17 to 20% of full BW. Gut fill and carcass weight increased ($P < 0.01$) in the summer (May to July, 2002) and fall (July to October, 2002), remained stable ($P = 0.25$ for gut fill, and $P = 0.82$ for carcass weight) in winter (October 2002 to February 2003), and decreased ($P = 0.014$ for gut fill and $P = 0.046$ for carcass weight) in spring (February to May, 2003). Gastrointestinal tract and EBW of grazing yak varied significantly across seasons ($P < 0.01$). The major components of the EBW of growing yaks are the carcass, head, hooves, blood, hide, internal organs, and GIT. As indicated in Table 4, the head, hide, and GIT comprised approximately 8% of the EBW, and the remaining components, including blood and hooves, comprised less than 8%.

Body Weight Change and Gut Fill

Gut fill increased ($P < 0.01$) in the second summer (May to July 2002) and the second fall (July to October 2002), coinciding with the period of compensatory growth. Gut fill gain in the second summer and the second fall was 5.78 and 7.58 kg, respectively, comprising 26.0 and 18.6% of BW gain in the same periods (Table 5). Gut fill loss in the second winter and the second spring was –1.57 and –3.83 kg, respectively, comprising 25.7 and 30.2% of BW loss in the same periods (Table 5). These results suggest that the seasonal growth responses of grazing yak should be measured/determined using the empty body method.

Chemical Composition of Grazing Yak

The body chemical composition data for yaks at the five different ages of slaughter are presented in Table 6. The water, CP, fat, ash, and energy content of EBW differed significantly ($P < 0.01$) between the second summer (May to July 2002) and the second fall (July to October 2002). During the subsequent weight-loss season, the second winter (October 2002 to February 2003) and the second spring (February to May 2003), there was no difference in CP ($P = 0.48$), fat ($P = 0.06$), or energy ($P = 0.14$) loss in EBW.

Seasonal changes in body chemical composition, as indicated by EBW components, are summarized in Table 7. The EBW gain in the second summer (May to July 2002) was 16.5 kg, compared with 33.1 kg in the following fall (July to October 2002). The proportions of water, CP, and crude fat in EBW gain were 72.0, 20.3, and 4.2%, respectively, in the second summer, and 69.3, 22.0, and 6.9% in the second fall. Further comparison of EBW data for the second summer and second fall revealed no difference in the water ($P = 0.77$), CP ($P = 0.77$), or fat ($P = 0.55$) contents of EBW gain, or in energy accumulation (5.01 and 6.30 MJ/kg of EBW gain; $P = 0.63$). Total energy accumulation during this second growth season was 291.07 MJ.

The EBW loss in the second winter (October 2002 to February 2003) was 4.3 kg, compared with 9.3 kg the following spring (February to May 2003) The proportions of water, CP, and crude fat in EBW loss were 31.2, 44.0, and 24.3%, respectively, in the second winter, and 65.4, 21.6, and 14.5% the following spring. The water and CP content of EBW loss differed significantly ($P < 0.01$) between the second winter and the following spring. The proportion of energy (MJ/kg of BW) mobilized in winter was greater ($P = 0.02$) than in spring (16.49 vs. 9.06 MJ/kg of BW). Total body energy loss in the second cold season (October 2002 to May 2003) was 147.8 MJ, reflecting 50.8% of the total body energy accumulated in the second growth (warm) season (May to October 2002). These data suggest that the yak may have evolved some

Table 6. Seasonal effects on the body chemical composition of 1- to 2-yr-old yak in Su-nan

Item	13 mo	15 mo	18 mo	22 mo	25 mo	SEM
Water, kg	28.22[a]	39.73[b]	62.48[c]	60.21[cd]	54.95[d]	1.977
Protein, kg	7.56[a]	10.20[b]	16.01[c]	14.80[cd]	13.39[e]	0.484
Fat, kg	0.67[a]	1.86[b]	5.58[c]	3.59[d]	2.24[be]	0.163
Ash, kg	1.46[a]	2.08[b]	3.39[c]	3.18[cd]	2.90[d]	0.116
Energy, MJ	153.25[a]	242.23[b]	478.61[c]	384.45[d]	310.34[e]	13.49

[a,b,c,d,e]Means were separated if the main effect of month was significant; therefore, within a row, means that do not have a common superscript differ, $P < 0.05$.

Table 7. Chemical composition of empty BW (EBW) gain of grazing yak by study period

Item	May to July 2002	July to October 2002	October 2002 to February 2003	February to May 2003	SEM
EBW gain, kg	16.52[a]	33.12[b]	–4.33[c]	–9.27[d]	1.827
Water, %	72.0[a]	69.3[a]	31.2[b]	65.4[a]	0.086
CP, %	20.3[a]	22.0[a]	44.0[b]	21.6[a]	0.055
Fat, %	4.2[a]	6.9[ab]	24.3[c]	14.5[bc]	0.044
Energy, MJ/kg	5.01[a]	6.30[a]	16.49[b]	9.06[a]	2.552

[a,b,c,d]Means within a row that do not have a common superscript differ, $P < 0.05$.

mechanisms for coping with extreme low temperatures that prevent further body CP and fat decomposition in the cold season. Zhao (1986) reported that Tibetan sheep have a very low rate of energy metabolism in winter to decrease the body tissue mobilization, and they can increase their energy metabolic rate above the basal level when confronted by a severe shortage of forage supply.

Water and CP were the major components of the chemical composition of EBW loss in yaks in winter (October 2002 to February 2003). In spring (February to May 2003), however, the proportion of water increased ($P < 0.01$), whereas the proportion of CP ($P < 0.01$) decreased. The resulting energy mobilized was 16.49 MJ/kg EBW in winter and 9.06 MJ/kg EBW in spring. These data suggest the presence of a physiological adaptation in the yak to cope with seasonal changes in forage and environmental conditions.

Conclusions

Energy retention (MJ/kg of BW gain) in the yak was the same in summer and fall. Energy content (MJ/kg of EBW) loss was much greater in winter than in spring. Approximately half the total energy retained during the second warm season following birth was mobilized during the subsequent cold season. Energy loss (MJ/kg of EBW mobilized) of yak was 16.49 MJ/kg of BW in winter and 9.06 MJ/kg of EBW in spring. The decrease in BW in grazing yak during the first cold season following birth was much less than that during the second cold season. The first weight loss period (first cold season, age 8 to 13 mo) was 2 mo shorter than the second weight loss period (second cold season, age 18 to 25 mo). We conclude that herders could exploit the efficient compensatory growth of the 1-yr-old yak following the first weight loss period and rear yaks to 18 mo of age for market or slaughter.

Implications

The results of our experiment demonstrate that the growth by yaks grazing native grassland is interrupted by the effects of the cold season on forage supply and yak body composition. Growth is not constant, and body weight fluctuates significantly by season throughout the first 2 yr of life; however, the body weight decrease in the cold season is followed by a large increase during the warm season. This pattern indicates highly efficient compensatory growth in the grazing yak, which could be exploited by herders in yak production. The higher proportion of gut fill associated with body weight change in this study demonstrates the importance of measuring yak growth responses to seasonal change on an empty, rather than full, body weight basis. That the retained energy mobilized by yak in winter is greater than that in spring suggests that yaks have developed self-protective mechanisms to survive the long, severe cold season of the Qinghai-Tibetan Plateau.

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