Journal of Animal and Veterinary Advances 11 (7): 919-923, 2012
ISSN: 1680-5593

Energy and Nitrogen Provided by Native Herbage to Sheep Grazing in Alpine Grasslands of the Qinghai-Tibetan Plateau

[1,2]Xiao Jinyu, [3]Zhang Changji, [1]Lu Yuexiang, [1]Wang Qin and [4]An Yufeng
[1]College of Pastoral Agriculture Science and Technology, Lanzhou University
[2]Key Laboratory of Grassland Agro-Ecosystems
[3]Faculty of Animal Science and Technology, Gansu Agricultural University, Lanzhou, Gansu, P.R. China
[4]Sunan Sheep Breeding Farm, Sunan, Gansu, P.R. China

Abstract: In Alpine pasturelands animals switch from higher land for summer and autumn grazing to lower land for winter and spring grazing. A grazing experiment using nine Gansu Alpine Merinos was carried out in Alpine grassland on the Qinghai-Tibetan plateau. Results for the quality of consumed herbage from the autumn pasture showed that the Digestible Energy (DE), Crude Protein (CP) content and CP:DE ratio were 9.15 MJ kg^{-1}, 10.8 g/100 g and 11.8 g MJ^{-1}, respectively and the CP level and the CP:DE ratio were optimal for nitrogen utilization. The dry matter intake changed significantly with seasons ($p<0.05$). For sheep grazing on winter pasture, the actual metabolizable energy intake was lower than maintenance requirements with a negative nitrogen balance ($p<0.05$), supplements should include both energy and protein feed. While grazing on spring pasture, sheep should be supplemented with energy feed expected to improve N utilization.

Key words: Grazing, Qinghai-Tibetan plateau, Gansu Alpine Merino, energy, nitrogen utilization, China

INTRODUCTION

A large part of North West China is covered by natural grassland on the Qinghai-Tibetan plateau, the quality and quantity of the herbage ingested by animals change seasonally when they move from higher land used for summer and autumn grazing to lower land for winter and spring grazing. The alpine pasturelands of the plateau are characterized by low temperature and high altitude and their high temporal variability in temperature and precipitation directly affects plant and animal productivity. During the vegetative growth season from May to September, there is an increased herbage supply which would be expected to increase animals' Body Weight (BW). As the herbage supply decreases in Winter, animals' BW decreases (Long *et al*., 1999) and some animals cannot survive the extended shortage of herbage supply which causes economic losses equal to 30% of the value of animal husbandry in the region (Ren and Zhu, 1995). This has resulted in a centuries' old grassland livestock production cycle where the livestock on the plateau is expected to satiate in Summer, fatten in Autumn, get thin in Winter and weak in Spring (Dong *et al*., 2006; Xue *et al*., 2005; Dong *et al*., 2003). This situation is still common and is becoming more prevalent in this area (Yang *et al*., 2011). In this harsh climate, many families rely mainly on animals for their survival. Sheep used for fibre and meat, graze all year round except for rams around mating time and ewes in pregnancy and lactation which are provided with concentrate supplements. Research studies have been done on the body weight change (Nie *et al*., 2002), sulfur nutrition (Yang *et al*., 1999) and relationship between daily gain or wool production and crude protein or plasma urea nitrogen levels in grazing sheep of this area (Ma *et al*., 1996). However, little research has been reported that investigates seasonal changes with animal nutrition in terms of energy and nitrogen, especially related to fattening in autumn even though the grass is withered and yellow. Energy and nitrogen are the main factors that limit productivity of merinos in China as herds are taken out to graze daily on locally grown forages that vary in quality and quantity seasonally (Ao and Feng, 1997). Information on the digestibility and metabolism of energy and nitrogen is required to better understand the reasons for the seasonal BW changes and to improve animal productivity. This knowledge will be valuable for planning and management of such grazing land. This study was conducted to determine the quality of the herbage and the digestibility and metabolism of energy and nitrogen in sheep grazing on the alpine-meadow grasslands of the Qinghai-Tibetan plateau.

Corresponding Author: Xiao Jinyu, Key Laboratory of Grassland Agro-Ecosystem, College of Pastoral Agriculture Science and Technology, Lanzhou University, Lanzhou, 730020 Gansu, China

Table 1: Natural condition of four seasonal grazing pastures on Qinghai-Tibetan plateau

Natural condition	Summer pasture	Autumn pasture	Winter pasture	Spring pasture
Grazing time	July-August	September-October	November-April of next year	May-June
Grassland type	Shrubs+grasses+sedges	Grasses	Grasses	Grasses
Altitude (m)	2780-3500	2750-2800	2700-2750	2750-2800
Temperature (°C)	14.5	8.6	-10.5	3.8
Precipitation (mm)*	111.6	96.4	2.6	43.1

*Weather information was from Su-nan Weather Station, 1952-1980

MATERIALS AND METHODS

The study was conducted in the Sunan Breeding Farm, approximately 22 km near to Sunan County town on the Northern end of the Tibetan plateau, Gansu province. The pastureland is used with a seasonal migration between different grazing areas. The natural condition of the pastures is shown in Table 1.

Nine esophageally-fistulated Gansu Alpine Merino wethers, approximately the same age and live weight were grazed on the native grassland with a herd of 40-60 animals for each study period. The animals were marked for identification and tied by a rope to made catching easy and provided with salt irregularly and water was available at the middle or end of the day; animals were kept inside during the night. The digestion and metabolism trial was done four times, from July 26th to Augest 8th 2007, from September 24th to October 7th 2007, from December 17-30th 2007 and from May 6-19th 2008. The trial was pre-term for 8 days for sheep to be adapted and pro-term for 6 days to sample, the sheep were dosed with Cr_2O_3.

Herbage samples collected from the fistulated wethers was analysed for Dry Matter (DM), Gross Energy (GE), Nitrogen (N) or Crude Protein (CP) (AOAC,1984), Neutral Detergent Fiber (NDF), Acid Detergent Fiber (ADF) and Acid Detergent Lignin (ADL) (Goering and van Soest, 1970) and IVDMD (Tilley and Terry, 1963). Fecal sample were collected from the rectum. Fecal output was estimated from the Cr_2O_3 concentration in feces. The individual daily fecal samples were divided into two sub-samples; one sub-sample was pooled and soaked with 2% H_2SO_4 for N analysis; the other sub-sample was dried in oven at 65°C, for DM, GE (AOAC,1984) and Cr_2O_3 analysis. Urine output was also estimated by bags containing pre-weighed degreased cotton. The collected urine was weighed 3 or 4 times a day. The cumulative urine weight was the daily output, assuming no urinary and N loss by evaporation. The squeezed urine was kept for N analysis, the addition of 50% H_2SO_4 to keep urine pH below 3.

Herbage intake was estimated with the ratio between fecal output, estimated with Cr_2O_3 and the herbage indigestibility, estimated with *in vitro*. The daily fecal output was revised by the recovery (96.7%) of the marker dose on autumn pasture (F = 0.967×marker dose (4 g)/day/fecal marker concentration, g g^{-1}) (Table 2). The recovery of the marker dose was measured using six other wethers grazing for 7 days. The wethers were bagged to collect total daily feces and the feces sampled for Cr_2O_3 analysis.

Table 2: Recovery rate of mark dose with sheep grazing on autumn pasture

Sheep	Fecal output (g day^{-1})	Cr_2O_3 Content of fecal (%)	Cr_2O_3 recovery (g day^{-1})	Cr_2O_3 recovery rate (%)
1	847.52	0.4604	3.9020	97.55
2	855.19	0.4559	3.8988	97.47
3	890.57	0.4487	3.9961	99.90
4	786.03	0.4696	3.6911	92.28
5	686.99	0.5514	3.7882	94.70
6	827.59	0.4755	3.9351	98.38
Mean±SE	815.65±29.30	0.4769±0.0153	3.8686±0.0450	96.71±1.1227

The metabolisable energy requirements for maintenance of the sheep were calculated from the fasting heat production (272 KJ/$kg^{0.75}$ day) for wethers as reported by applying a k_m of 0.72 (ARC, 1980) and an extra increase in energy expenditure of 6% due to the physical activity of grazing.

The data of nutrients content and digestibility and metabolism were analyzed by the Least Significant Ratios (LSR) test to compare pasture means (Steel and Torrie, 1980).

RESULTS AND DISCUSSION

Herbage nutrients and intake: The values of herbage nutrients varied from July in 2007 to May in 2008 (Table 3). The crude protein and IVDMD were lowest on the winter pasture and highest on the spring pasture. In Table 4 with decreased CP, the herbage intake by sheep decreased from the summer (84.3 g/$kg^{0.75}$day) to the winter (73.5 g/$kg^{0.75}$day) pasture. Low nitrogen diets are one of the reasons for reduced intake. Van Soest (1994) suggested that a threshold of about 6-8% crude protein was required for optimum rumen function while the CP (4.6 g/100 g) of the herbage from the winter pasture was lower than that critical level. This level is below the nitrogen requirement and both intake and digestibility falls off (Nocek and Russell, 1988; Milford and Minson, 1965). Moreover, the cold conditions in winter affect the

Table 3: Nutritional value of native pasture consumed by sheep (Mean±SE)

Nutritional value	Summer pasture	Autumn pasture	Winter pasture	Spring pasture
IVDMD (%)	56.6±1.900[b]	51.9±1.100[b]	35.3±1.400[d]	64.8±1.900[a]
CP (g/100 g DM)	14.6±0.900[b]	10.8±0.600[c]	4.6±0.400[d]	21.5±1.000[a]
DE (MJ kg^{-1})	8.28±0.20[b]	9.15±0.18[a]	4.30±0.13[c]	9.76±0.22[a]
CP/DE (g MJ^{-1})	17.6±0.100[b]	11.8±0.200[c]	10.8±0.200[c]	22.1±0.100[a]
NDF (g/100 g DM)	63.3±0.800[b]	59.4±1.500[b]	70.5±0.600[a]	52.9±2.500[c]
ADF (g/100 g DM)	35.3±0.600[b]	36.7±0.700[b]	50.4±2.400[a]	31.3±0.800[c]
ADL (g/100 g DM)	6.66±0.12[b]	5.79±0.25[bc]	7.94±1.05[a]	3.43±0.23[c]
DM (g/100 g fresh matter)	39.2±2.100[c]	61.8±1.200[b]	89.0±0.700[a]	24.6±1.600[d]

DM; Dry Matter, IVDMD: *In vitro* Digestibility of Dry Matter, CP: Crude Protein, DE: Digestible Energy, NDF: Neutral Detergent Fiber, ADF: Acid Detergent Fiber and ADL: Acid Detergent Lignin; [a-c]: Within a row different letters are different at $p<0.05$

Table 4: Energy and nitrogen digestion and metabolism of sheep grazing on four seasonal pastures (Mean±SE)

Digestion and metabolism	Summer pasture	Autumn pasture	Winter pasture	Spring pasture
Body weight (kg)	58.6±5.8[a]	65.3±4.7[a]	58.0±5.4[a]	52.8±5.0[a]
Daily gain (g day^{-1})	106±24.5[a]	111.7±33.9[a]	-86.9±26.8[c]	-36.6±12.8[b]
DM intake (g/$W^{0.75}$ kg day^{-1})	84.3±2.0[a]	81.8±5.1[a]	73.5±9.5[ab]	60.5±1.5[b]
Gross energy intake (MJ/$W^{0.75}$ kg day^{-1})	1.41±0.04[a]	1.47±0.09[a]	1.19±0.16[b]	1.07±0.03[c]
Fecal energy (MJ/$W^{0.75}$ kg day^{-1})	0.68±0.02[a]	0.66±0.04[a]	0.73±0.10[a]	0.43±0.01[c]
Energy digestibility (%)	51.8±0.6[a]	54.9±1.3[a]	28.6±7.4[c]	59.8±0.7[a]
Digestible energy intake (MJ/$W^{0.75}$ kg day^{-1})	0.73±0.01[ab]	0.81±0.06[a]	0.46±0.07[c]	0.64±0.02[b]
Metabolizable energy intake (MJ/$W^{0.75}$ kg day^{-1})	0.60±0.01[a]	0.66±0.05[a]	0.37±0.06[c]	0.52±0.01[b]
MEI/ME_m	1.5	1.7	<0.9	1.3
N intake (g/$W^{0.75}$ kg day^{-1})	2.11±0.05[a]	1.52±0.10[c]	0.59±0.08[d]	2.25±0.06[a]
Fecal N (g/ $W^{0.75}$ kg day^{-1})	0.95±0.03[a]	0.62±0.05[c]	0.61±0.09[c]	0.69±0.04[c]
Urinary N (g/$W^{0.75}$ kg day^{-1})	0.78±0.07[c]	0.52±0.06[cd]	0.22±0.02[e]	1.25±0.16[a]
Urinary N/N intake (%)	0.37±0.27[b]	0.32±0.26[b]	0.39±0.07[ab]	0.46±0.06[a]
N retained of N intake (%)	18.0±1.9[b]	27.2±2.8[a]	-50.1±13.4[c]	20.6±5.0[ab]

MEI: Metabolizable Energy Intake; Metabolizable energy intake = Digestible energy intake×0.82; ME_m: Metabolizable Energy for maintenance, ME_m = 0.4 MJ on the spring, summer and autumn pasture, ME_m>0.4 MJ due to below the thermo neutral zone (10°C) on the winter pasture; [a-d]: Within a row different letters are different at $p<0.05$

intake of a feed. Under cold stress, the digestibility of DM in sheep was found to decrease 0.31% with every 1°C of temperature decrease (NRC, 1981). As the DM digestibility decreases, feed intake also decreases (Van Soest, 1982).

Metabolisable energy intake expressed as a multiple of ME required for Maintenance (ME_m), was 1.7, 1.7 and 1.3, respectively when sheep were grazing on the summer, autumn and spring pasture. However, it was <0.9 on the winter pasture due to ME_m >0.4 MJ below thermo neutral zone (10°C) (NRC, 1981). It means that the actual metabolisable energy intake did not meet the energy requirements for maintenance when sheep grazing on the winter pasture except for the other pastures which was explained that the energy digestibility was lower ($p<0.05$). The BW was lower on the spring than on the winter pasture even though the actual metabolisable energy intake was higher than the ME_m for sheep grazing on the spring pasture. The reason is that the BW was increasing step by step after it has gone down to a threshold when the temperature goes up to -5°C from winter to spring pasture (Research Workgroup of Climate and Husbandry in Pastoral of China, 1988).

Nitrogen utility: Due to the higher CP level on the spring pasture, N intake of sheep grazing on the spring pasture was close to that on the summer pasture although, dry matter intake was lower on the spring pasture and the N intakes on the spring and summer pasture were significant higher than those on the autumn and winter pastures ($p<0.05$). Fecal nitrogen is a main loss during digestion and metabolism; it is a steady loss (Van Soest, 1994). It is a reason why fecal nitrogen output was not significantly different between the autumn, winter and spring pastures.

The urinary nitrogen, the total nitrogen in the urine, was highest ($p<0.05$) on the spring pasture and the lowest on the autumn pasture. High urinary N as a percentage of N intake indicates high protein or inorganic N intake and rapid rumen digestion resulting in ammonia production in excess of microbial needs (Merkel *et al*., 1999; Van Soest, 1994) which can be used to explain why the urinary N as a percentage of N intake was higher on the spring and summer pasture. In addition, the CP:DE ratio (22.1 g MJ^{-1}) was the highest on the spring pasture, revealing that the energy was mostly insufficient for synthesizing microbial protein in the rumen and unused ammonia was excreted as urine. However, the DE or CP content of herbage was lowest from the winter pasture with the lowest N retention which showed that both CP and DE limited synthesis of microbial protein.

Although, the CP (10.8 g/100 g) content and CP:DE ratio (11.8 g MJ^{-1}) of herbage from the autumn pasture were lower than those from the summer pasture, the CP content was near to the threshold level (11%) for synthesizing microbial protein (Satter and Roffler, 1981), so the microbial protein was being synthesized efficiently and the highest N retention occurred in sheep grazing on the autumn pasture.

CONCLUSION

This study shows that the CP or DE content and CP:DE ratio of herbage consumed by sheep are optimal on the autumn pasture so, the N retention is highest which may be one of the reasons why the grazing animals fatten even when the herbage becomes withered or yellow in autumn. The quality of ingested herbage is worst on the winter pasture and the nitrogen retention is the lowest; sheep should be supplemented with energy and protein supplements. Although, the CP content of the herbage is highest on the spring pasture, the energy is low and energy feed was expected to improve N utilization.

ACKNOWLEDGEMENTS

The English language of the study was improved by Mrs. Margaret Cargill, Adjunct Senior Lecturer, School of Agriculture, Food and Wine, The University of Adelaide. The research was supported by International Centre for Tibetan Plateau Ecosystem Management, Lanzhou University by State Key Laboratory of Grassland Farming Systems and by the Fundamental Research Funds for the Central Universities (lzujbky-2011-111).

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