



## Seasonal Variations in Voluntary Intake and Apparent Digestibility of Forages in Goats Grazing on Introduced *Leymus chinensis* Pasture

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**ABSTRACT:** The nutrient composition of pasture, voluntary intake and digestibility of diet ingested by goats grazing on an introduced *Leymus chinensis* pasture were measured across spring (May), summer (July), autumn (October) and winter (March). In each season, 12 Inner Mongolian Cashmere goats (6 wethers and 6 does with an average live weight of 22.2±1.3 kg and 19.5±0.8 kg, respectively) were used to graze on a 2 hectares size paddock. Diet selection was observed and the plant parts selected by grazing goats and whole plant *L. chinensis* were sampled simultaneously. The alkane pair C<sub>32</sub>:C<sub>33</sub> and C<sub>36</sub> were used to estimate intake and digestibility, respectively. The results showed that the plant parts selected by goats had higher crude protein (CP) and lower acid detergent fiber (ADF) and neutral detergent fiber (NDF) than the whole plant, especially in the autumn and winter. The voluntary intake of dry matter (DM), CP, ADF, NDF, and metabolizable energy (ME) by goats was highest in summer (p<0.05). The goats ingested more CP, ME, and less ADF in spring than in autumn (p<0.05). The intakes of DM, CP, and ME were lowest in winter (p<0.05). There were significant differences in nutrient intake between wethers and does in each season, except for the ADF and ME intake per metabolic weight (LW<sup>0.75</sup>). The nutrient digestibilities were higher in spring and summer, and decreased significantly during the autumn and winter (p<0.05). Goats, especially wethers, had a relative constant NDF digestibility across seasons, however, the apparent digestibility of CP in both wethers and does, decreased to negative values in winter. The grazing goats experienced relatively sufficient nutrients supply in spring and summer, and a severe deficiency of CP and ME in winter. (**Key Words:** *Leymus chinensis*, n-Alkanes, Intake, Digestibility, Goat)

### INTRODUCTION

*Leymus chinensis* is a perennial species of Gramineae, which is widely distributed in the eastern end of the Eurasian steppe zone, including the Songnen plain and the eastern Inner Mongolian plateau in China (Sun and Zhou, 2007). The high palatability, high trampling tolerance, and high protein content make it an ideal species for both

grazing and hay production (Wang and Earle, 1997). However, almost all *L. chinensis* grassland of China including the Songnen plain have been degraded in both pasture quality and productivity due to the overstocking of herbivores (Sun et al., 2008). The serious degradation is restricting the grassland domestic industry and threatening the ecological environments. Facing this serious situation, *L. chinensis* had been introduced to renew native *L. chinensis* communities or rebuild artificial *L. chinensis* pastures, due to its positive characteristics such as the vigorous vegetative propagation and high tolerance to arid, saline, alkaline and low fertility conditions (Huang et al., 2002; Sun et al., 2011).

The feed value of *L. chinensis* products have been studied for some animal species (Zai et al., 1994; Liu and Lou, 2006; Zhao, 2008; Wang, 2013). Many studies and practices indicate that *L. chinensis* hay is a high quality

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roughage resource for almost all dry lot feeding herbivores, especially in winter (Lou et al., 2006; Wang, 2013). However, the nutritional and ecological studies about fresh *L. chinensis* used as a main dietary component are rather limited. Knowing its nutritive value, digestibility of nutrients and voluntary intake are essential to efficient use of pasture for the herbivore industry, especially for a introduced *L. chinensis* grassland. Until now, only Sun and Zhou (2007) reported the seasonal changes in voluntary intake and digestibility by sheep grazing introduced *L. chinensis* pasture.

Sheep and goats are both the principal domestic animal species grazing on the *L. chinensis* pasture of the Songnen Plain of northeastern China, impacting on the domestic production and grassland ecosystem health. Sun et al. (2008) showed that the diet selection, the efficiency of nutrient utilization, and voluntary intake of grazing goats varied with seasons and significantly differed from sheep. Therefore, the purpose of this research was to determine the diet selection, nutrients intake and digestibility using the n-alkane as markers in Inner Mongolian Cashmere goats grazing on introduced *L. chinensis* grassland across the four seasons. Additionally, the possible effect of the sex of goats on these parameters was investigated. This information is essential to generate a comprehensible understanding of the utilization of introduced pasture with the goal of increasing goat production.

## MATERIALS AND METHODS

### Experimental site and pasture

This study was carried out at the Northeast Normal University Research Station, situated 171.1 m above sea level, at Songnen plain, Jilin province, China (43°59'N, 123°6'E). The climate is continental with an average annual precipitation of 470 mm (average of last 20 years), and 80% of it occurring between June and August. The mean annual temperature in the study area is 4.9°C with a minimum mean of -16.4 (January) to a maximum of 23.2°C (June).

The introduced *L. chinensis* grassland was a homogeneous vegetation type with nearly 100% of *L. chinensis*. The *L. chinensis* germinates in early May, reaching maximum above-ground biomass in mid August or early September.

### Experimental design and sampling

Two hectares of fenced perennial introduced *L. chinensis* pasture was used for this study. The grazing trials were conducted in spring (May 20 to June 10, 2004), summer (July 20 to August 10, 2004), autumn (September 30 to October 21, 2004) and winter (March 15 to April 5, 2005). The diets of grazing goats reflected the evolution of the *L. chinensis* growth and the nutritive value across the

four seasons. The grazing trial comprising a preliminary adaptation period of 7 days for animals to get used to the diets and experimental conditions, followed by a sampling period of 15 days.

The same 12 inner Mogolian cashmere goats, 6 wethers (22.2±1.3 kg initial body weight) and 6 does (19.5±0.8 kg initial body weight) selected from a commercial flock on the farm of Northeast Normal University Research Station, were used in the grazing trial. The females were non-pregnant in spring, while in summer they were in the first month of pregnancy. Goats were weighed at the beginning and end of each experimental period and treated against helminths with Ivermectin injection (Lehua, Zhejiang) at the beginning of the trial. The goats were allowed to graze in the paddock from about 6 am to 6 pm daily and had free access to mineral blocks. Water was available before and after the grazing period. After 7 days adjustment period, fecal samples were collected from the rectum of each goat from days 8 to 10, to establish "background" concentration of herbage C<sub>32</sub> and C<sub>36</sub> in the faeces. On day 11, C<sub>32</sub>/C<sub>36</sub> Captec alkane controlled release capsules (CRC, Fernz Health and Science, NZ), were administered to the rumen of each goat.

The capsule was designed to release 50 mg C<sub>32</sub> and 50 mg C<sub>36</sub> per day for approximately 20 days. The equilibrium of the alkanes in the rumen was achieved within seven days according to the product instruction. However, these release rates were calculated on fistulaed sheep grazing on ryegrass and clover pasture. In order to measure the actual release rate of CRC for the present experimental conditions, goats were fitted with a fecal collection harness (Cole et al., 1996) from days 16 to 18, for measuring daily total fecal output of each animal. In the last 4 days (days 19 to 22), harnesses were not used and rectal grab samples were obtained daily. During the collection period, daily total fecal output was recorded individually. After the daily fecal output was completely mixed, a sub-sample was collected and frozen for subsequent analysis.

The samples of herbage were taken daily from days 19 to 22 both as the whole-plant and as simulated samples. To determine the plant parts consumed by goats throughout the experiment, a direct observation of the animal's feeding behavior was conducted during each sampling period. Throughout the observation sessions, goats were selected randomly and observed for a time period of about 5 min during which bite-like samples were clipped or plucked, and the plant parts eaten were recorded as Kababya et al. (1998). The simulated samples were collected and were immediately frozen for subsequent n-alkane and chemical analysis.

### Chemical analysis

Sub-samples of feces and herbage were dried at 60°C

in a forced-air oven until constant weight and milled through 1-mm screen. Ground samples were analyzed for dry matter (DM), organic matter (OM), crude protein (CP) and gross energy (GE) following the procedures of AOAC (1995). Acid detergent fiber (ADF) and neutral detergent fibre (NDF) were determined as described by Van Soest et al. (1991).

### Alkane analysis

The samples of herbage and feces collected for alkane analysis were immediately frozen at  $-20^{\circ}\text{C}$  and then freeze-dried and milled through a 1-mm screen. Concentrations of n-alkanes in herbage and feces were analyzed in duplicate by direct saponification as described by Sun et al. (2008).

### Calculations

Dry matter intake (DMI, kg DM/d) was estimated from the ratio of naturally occurring and dosed alkanes ( $C_{33}:C_{32}$ ) according to the equation proposed by Mayes et al. (1986):

$$\text{DMI} = \frac{D_{32}}{\frac{F_{32}}{F_{33}} \times H_{33} - H_{22}} \quad (1)$$

Where  $H_{33}$ ,  $F_{33}$ ,  $H_{32}$ , and  $F_{32}$  are the herbage and fecal concentrations of the odd-chain ( $C_{33}$ ) and even-chain ( $C_{32}$ ) n-alkanes respectively (mg/kg DM), and  $D_{32}$  is the actual release rate of even-chain n-alkane (mg/kg DM). The actual release rate of  $C_{32}$  alkane dosed via CRC were calculated as equation (2):

$$D_{32} = \frac{(F_{32} - B_{32}) \times FO}{AFR_{32}} \quad (2)$$

Where  $F_{32}$  is the mean fecal concentration of even chain n-alkane after CRC dosed,  $B_{32}$  is the background concentration of even-chain n-alkane before CRC administrated; FO is the mean fecal DM output measured during 3 days after CRC administration;  $AFR_{32}$  is the recovery rate of  $C_{32}$  alkane in feces measured in previous study (Sun et al., 2008).

Dry matter digestibility (DMD) was then calculated using the alkane  $C_{36}$  as the following equation (3) (Dove and Mayes, 1991):

$$\text{DMD} = 1 - ((D_{36} + \text{DMI} \times H_{36}) / F_{36}) / \text{DMI} \quad (3)$$

Where  $D_{36}$  is the amount (mg/d) of alkane ( $C_{36}$ ) released from the CRC;  $H_{36}$  is  $C_{36}$  alkane concentration in *L. chinensis*,  $F_{36}$  is the  $C_{36}$  alkane concentration in feces.

The daily intake was then calculated as DMI per kg of metabolic live weight ( $\text{LW}^{0.75}$ ) in order to compare the

seasonal variations as the live weight of the goats varied significantly. The live weight of the goats at the end of each seasonal period was used in the calculations.

Intakes and digestibility of GE, OM, CP, NDF, and ADF were calculated based on DMI (MJ or g/d), their concentrations (g/kg DM) in the diet components (simulated samples) and fecal samples. Digestible energy (DE) content of the pasture was calculated as the difference between gross energy intake and the fecal energy. Metabolizable energy content was then calculated as 0.82 DE (NRC, 1981).

### Statistical analysis

Statistical analyses were carried out using the SPSS for windows 17.0 program (SPSS Inc., Chicago, IL, USA). The data were presented as means and standard error of means unless otherwise stated. The effects of the seasons and sex on the herbage intake and digestibility were analyzed by two-way analysis of variance (ANOVA). Significant differences between means were tested by the Tukey test.

## RESULTS

### The parts and composition of *L. chinensis* selected by goats

The parts of *L. chinensis* consumed by goats varied among seasons (Table 1). In spring, the *L. chinensis* spike was the main diet component of goats and only a small quality of tender leaves were selected. The bite depth of plant was about  $10.2 \pm 2.4$  cm during the ear sprouting period. However, with the decrease in abundance of spikes in summer, leaves became gradually the main diet component and the bite depth was  $7.6 \pm 1.8$  cm. With the herbage maturing, bite depth decreased gradually to only  $4.5 \pm 1.2$  cm in winter.

### Chemical composition of plant parts selected by goats and the whole-plant of *L. chinensis*

The chemical compositions of *L. chinensis* whole-plant and of simulated samples in four seasons are shown in Table 2. There were no significant changes in GE among seasons or between the whole plant and the parts selected by goats. While the CP contents of whole plant decreased significantly from spring to winter ( $p < 0.05$ ), the parts selected by goats had relatively higher CP than those of

**Table 1.** The *L. chinensis* parts and bite depth selected by grazing cashmere goats

Season	Parts selected	Bite depth (cm)
Spring	Spikes+less leaves	$10.2 \pm 2.4$
Summer	Leaves	$7.6 \pm 1.8$
Autumn	Leaves	$6.3 \pm 1.6$
Winter	Leaves	$4.5 \pm 1.2$

**Table 2.** Seasonal variation of nutrients content of *L. chinensis* whole plant and the parts selected by goats

	Whole-plant				Parts selected by goats				SE
	Spring	Summer	Autumn	Winter	Spring	Summer	Autumn	Winter	
GE (MJ/kg)	22.30	19.90	21.60	20.10	18.38	19.91	19.82	18.47	1.71
DM (%)	91.34 <sup>ab</sup>	95.03 <sup>cd</sup>	93.24 <sup>bc</sup>	90.80 <sup>a</sup>	93.50 <sup>c</sup>	94.61 <sup>cd</sup>	95.92 <sup>d</sup>	95.10 <sup>cd</sup>	0.69
CP (%)	10.26 <sup>a</sup>	9.42 <sup>b</sup>	2.89 <sup>d</sup>	2.21 <sup>d</sup>	10.71 <sup>ab</sup>	9.96 <sup>ab</sup>	4.67 <sup>c</sup>	2.56 <sup>d</sup>	0.39
ADF (%)	31.41 <sup>a</sup>	33.20 <sup>a</sup>	44.61 <sup>cd</sup>	49.12 <sup>d</sup>	33.95 <sup>ab</sup>	33.39 <sup>a</sup>	40.07 <sup>b</sup>	42.58 <sup>c</sup>	2.05
NDF (%)	59.91 <sup>a</sup>	64.83 <sup>ab</sup>	78.02 <sup>d</sup>	81.44 <sup>d</sup>	61.26 <sup>ab</sup>	66.28 <sup>ab</sup>	60.07 <sup>a</sup>	69.20 <sup>b</sup>	2.76

SE, standard error; GE, gross energy; DM, dry matter; CP, crude protein; ADF, acid detergent fiber; NDF, neutral detergent fiber. Values on the same row with different superscripts differ significantly ( $p < 0.05$ ).

whole plant, especially in autumn ( $p < 0.05$ ). The NDF and ADF contents of both whole plant and parts selected by goats were higher in autumn and winter than those in spring and summer ( $p < 0.05$ ). However, the parts selected by goats contained lower NDF and ADF in autumn and winter than other seasons ( $p < 0.05$ ). Compared with the whole plant, the parts selected by goats had a relatively higher and constant DM content ( $p < 0.05$ ).

#### The n-alkane content

As shown in Table 3, the individual alkanes present in the highest concentrations were C<sub>31</sub>, C<sub>29</sub>, and C<sub>33</sub> for both the whole *L. chinensis* and parts. The concentrations of odd-chain alkanes were relatively low, C<sub>32</sub> was not detectable in spring and summer, and only a trace level could be detected in autumn and winter. The individual alkanes concentration of *L. chinensis* whole plant and parts varied from seasons, however, the seasonal change tendency in alkane concentration of plant parts were different.

After correction with "background" concentrations and fecal recovery, the actual CRC release rates of C<sub>32</sub> and C<sub>36</sub> from capsules in spring, summer, autumn and winter were 52.3, 53.5, 52.7, 51.6 mg/d and 52.6, 52.9, 53.1, 50.8 mg/d for wethers, and 47.8, 48.5, 49.8, 48.2 mg/d and 48.1, 48.6, 49.1, 47.9 mg/d for does, respectively. The corresponding release rates supplied by the manufacturer were 50 mg/d for both C<sub>32</sub> and C<sub>36</sub>.

#### Nutrient intake of goats grazing on introduced *L. chinensis* pasture

The estimates of nutrient intake using the pair C<sub>31</sub>:C<sub>32</sub>

are presented in Table 4. The season had significant effects on the daily intake of nutrients. The voluntary intake of DM, CP, ADF, NDF, and metabolizable energy (ME) by grazing cashmere goats were highest in summer ( $p < 0.05$ ). The grazing goats ingested more CP, ME, and less ADF in spring than in autumn ( $p < 0.05$ ). The intakes of DM, CP, and ME were lowest in winter ( $p < 0.05$ ). When calculated based on metabolic live weight, the intakes of DM, CP, ADF, NDF, and ME were also found the highest in summer and the lowest values in winter. The intakes of CP, NDF, and ME in spring were higher than those in autumn ( $p < 0.05$ ).

The sex had a significant effect on the voluntary intakes of goats. Wethers showed a higher ( $p < 0.05$ ) intake of DM, CP, ADF, NDF, and ME than does in each season. However, no sex differences were found in the intakes of ADF and ME when calculated based on metabolic weight ( $LW^{0.75}$ ).

#### Nutrient digestibility and metabolizable energy of diet consumed by goats grazing on introduced *L. chinensis* pasture

The estimates of ME content and apparent digestibility of DM, CP, NDF, ADF, and GE using n-alkane C<sub>36</sub> are presented in Table 5. The season had a significant effect on the ME content and the nutrients digestibility of *L. chinensis* consumed by goats ( $p < 0.01$ ). However, no apparent sex effects were found in ME and nutrients digestibility of diet. The inter-action of season and sex only was found in DM digestibility. The digestibility of DM and contents of GE and ME in the diet for wethers decreased significantly from spring to winter ( $p < 0.05$ ), but only the GE digestibility and ME content in the diet of does followed the similar pattern.

**Table 3.** The n-alkanes concentration patterns of whole *L. chinensis* or parts selected by goats (mg/kg)

n-alkane	Whole <i>L. chinensis</i>				Parts selected			
	Spring	Summer	Autumn	Winter	Spring	Summer	Autumn	Winter
C <sub>25</sub>	2.7	5.1	8.7	13.2	59.80	6.84	10.16	16.27
C <sub>27</sub>	12.3	15.3	22.4	35.6	91.33	12.01	30.28	47.08
C <sub>29</sub>	38.5	42.1	67.4	87.9	71.81	30.46	98.67	116.27
C <sub>31</sub>	171.9	152.5	231.1	342.1	150.34	93.25	287.02	452.52
C <sub>32</sub>	0	0	2.8	3.6	0	0	2.4	3.7
C <sub>33</sub>	41.3	39.8	57.5	79.6	31.19	30.68	72.6	93.88
Total	266.7	254.8	389.9	562	404.47	193.24	501.13	730.13

**Table 4.** Seasonal differences of nutrients intake by wethers and does grazing on introduced *L. chinensis* pasture

Sex (SX)	Season (SN)	Per goat					Per kg metabolic weight (LW <sup>0.75</sup> )				
		DM (g/d)	CP (g/d)	ADF (g/d)	NDF (g/d)	ME (MJ/d)	DM (g/d)	CP (g/d)	ADF (g/d)	NDF (g/d)	ME (MJ/d)
Wether	Spring	1,084 <sup>a</sup>	111.22 <sup>a</sup>	368.02 <sup>a</sup>	664.06 <sup>a</sup>	12.37 <sup>a</sup>	84.49 <sup>a</sup>	8.67 <sup>a</sup>	27.9 <sup>a</sup>	51.76 <sup>a</sup>	0.96 <sup>a</sup>
	Summer	1,267.5 <sup>b</sup>	126.24 <sup>b</sup>	423.22 <sup>b</sup>	840.1 <sup>b</sup>	16.62 <sup>b</sup>	91.91 <sup>b</sup>	9.15 <sup>b</sup>	30.69 <sup>b</sup>	60.92 <sup>b</sup>	1.09 <sup>b</sup>
	Autumn	1,076.5 <sup>a</sup>	50.27 <sup>c</sup>	431.35 <sup>b</sup>	646.65 <sup>ac</sup>	9.74 <sup>c</sup>	69.28 <sup>c</sup>	3.23 <sup>c</sup>	27.76 <sup>a</sup>	41.61 <sup>d</sup>	0.63 <sup>c</sup>
	Winter	897.6 <sup>c</sup>	22.98 <sup>d</sup>	382.2 <sup>a</sup>	621.23 <sup>ac</sup>	7.12 <sup>d</sup>	65.24 <sup>d</sup>	1.67 <sup>d</sup>	27.78 <sup>a</sup>	45.15 <sup>d</sup>	0.52 <sup>d</sup>
Does	Spring	729.3 <sup>d</sup>	74.83 <sup>e</sup>	247.6 <sup>c</sup>	446.77 <sup>d</sup>	8.40 <sup>e</sup>	72.64 <sup>e</sup>	7.45 <sup>e</sup>	24.66 <sup>c</sup>	44.5 <sup>d</sup>	0.84 <sup>e</sup>
	Summer	912.4 <sup>c</sup>	90.88 <sup>f</sup>	304.65 <sup>d</sup>	604.74 <sup>c</sup>	12.06 <sup>a</sup>	86.73 <sup>a</sup>	8.64 <sup>a</sup>	28.96 <sup>ab</sup>	57.48 <sup>b</sup>	1.15 <sup>b</sup>
	Autumn	764.3 <sup>d</sup>	35.69 <sup>g</sup>	306.26 <sup>d</sup>	459.12 <sup>d</sup>	6.99 <sup>d</sup>	60.76 <sup>f</sup>	2.84 <sup>f</sup>	24.34 <sup>c</sup>	36.5 <sup>c</sup>	0.56 <sup>cd</sup>
	Winter	667.9 <sup>e</sup>	17.1 <sup>h</sup>	284.39 <sup>d</sup>	462.25 <sup>d</sup>	5.37 <sup>f</sup>	62.71 <sup>df</sup>	1.61 <sup>d</sup>	26.7 <sup>ac</sup>	43.4 <sup>d</sup>	0.5 <sup>d</sup>
SEM		12.68	1.44	9.64	15.38	0.36	1.37	0.12	0.80	1.26	0.03
SN		**	**	**	**	**	**	**	**	**	**
SX		**	**	**	**	**	**	*	NS	*	NS
SN×SX		**	**	NS	NS	**	NS	*	NS	NS	NS

DM, dry matter; CP, crude protein; ADF, acid detergent fiber; NDF, neutral detergent fiber; ME, metabolizable energy; SEM, standard error of the mean; NS, non-significant.

Different superscripts within the same column indicate significant differences ( $p < 0.05$ ), \*\*  $p < 0.01$ , \*  $p < 0.05$ .

The digestibility of CP, ADF, and NDF of wethers and does followed a similar pattern, no significant differences were found between spring and summer ( $p > 0.05$ ) and the ADF and NDF digestibility were also similar between autumn and winter. However, the CP digestibility decreased significantly to a negative value in winter.

## DISCUSSION

A comparison of seasonal nutrient concentrations of *L. chinensis* was necessary to gain an insight into its feeding value and to identify whether any differences observed could have a biological relevance to voluntary intake and apparent digestibility of nutrients. Many studies that have compared seasonal nutrient patterns of whole plant of *L. chinensis*, and found the content of GE and DM were

constant across the seasons but CP, ADF, and NDF contents varied significantly (Wang, et al., 2005; Sun and Zhou, 2007). The similar findings were obtained in this study.

However, to our knowledge, there seemed to be no available data on the comparison of the nutrient patterns between the whole plant of *L. chinensis* and the plant parts selected by grazing animals. In present study, the GE was similar between the whole plant *L. chinensis* and parts selected by goats in each season; it was accorded with the physiological characteristic of animal intake for energy. The plant parts selected by goats had similar DM, CP, ADF, and NDF contents as whole *L. chinensis* when the plant was flourishing during the spring and summer, but had a higher level of DM and CP content, a lower ADF and NDF during the autumn and winter when the plant quality and availability were decreasing. These results are in agreement

**Table 5.** Metabolizable energy content and nutrient digestibility of diets consumed by cashmere goats grazing on *L. chinensis* pasture

Sex (SX)	Season (SN)	DM (%)	CP (%)	ADF (%)	NDF (%)	GE (%)	ME (MJ/kg DM)
Wether	Spring	75.09 <sup>a</sup>	82.32 <sup>a</sup>	73.52 <sup>a</sup>	72.76 <sup>a</sup>	75.67 <sup>a</sup>	11.41 <sup>a</sup>
	Summer	70.73 <sup>b</sup>	77.89 <sup>a</sup>	77.7 <sup>a</sup>	75.16 <sup>a</sup>	80.33 <sup>b</sup>	13.11 <sup>b</sup>
	Autumn	55.56 <sup>c</sup>	40.31 <sup>b</sup>	56.36 <sup>b</sup>	62.32 <sup>abc</sup>	55.67 <sup>ce</sup>	9.04 <sup>c</sup>
	Winter	50.82 <sup>d</sup>	-13.37 <sup>c</sup>	44.59 <sup>b</sup>	62.93 <sup>abc</sup>	52.33 <sup>d</sup>	7.94 <sup>d</sup>
Does	Spring	72.91 <sup>e</sup>	75.6 <sup>a</sup>	72.5 <sup>a</sup>	70.8 <sup>ab</sup>	76.33 <sup>a</sup>	11.5 <sup>a</sup>
	Summer	71.87 <sup>be</sup>	79.05 <sup>a</sup>	68.89 <sup>a</sup>	74.57 <sup>a</sup>	82.00 <sup>b</sup>	13.4 <sup>b</sup>
	Autumn	54.54 <sup>c</sup>	34.27 <sup>b</sup>	56.33 <sup>b</sup>	49.62 <sup>c</sup>	56.33 <sup>c</sup>	9.15 <sup>c</sup>
	Winter	51.76 <sup>d</sup>	-6.79 <sup>c</sup>	44.78 <sup>b</sup>	56.01 <sup>bc</sup>	53.00 <sup>de</sup>	8.04 <sup>d</sup>
	SEM	0.69	1.7	5.21	6.8	1.4	0.23
SN		**	**	**	**	**	**
SX		NS	NS	NS	NS	NS	NS
SN×SX		**	NS	NS	NS	NS	NS

DM, dry matter; CP, crude protein; ADF, acid detergent fiber; NDF, neutral detergent fiber; GE, gross energy; ME, metabolizable energy; SEM, standard error of the mean; NS, non-significant.

Different superscripts within the same column indicate significant differences ( $p < 0.05$ ), \*\*  $p < 0.01$ , \*  $p < 0.05$ .

with those reported by Raghavendra et al. (2002) and Ferreira et al. (2005), who found that goats select tree leaves or forage which are richer in nitrogen and lower in fiber when water and mineral needs are covered. This finding indicated that goats adjust foraging behavior to improve the food quality in order to compensate for reduced availability. In fact, the grazing behavior changes were also found in this study. The phenomenon was accorded with the intake strategy of herbivore (Allden and Whittaker, 1970). Therefore, to objectively reflect the nutrients ingested by grazing goat, it is necessary to understand the actual nutritive value of plant parts selected by grazing animals.

Although the n-alkane technique has been widely used to evaluate the nutritional status of grazing animals, the actual release rates of "CRC" need to be considered for each specific situation (Dove and Mayes, 2005; Ferreira et al., 2007; Sun et al., 2008). The CRC used in this study was designed for sheep to deliver 50 mg/d of both C<sub>32</sub> and C<sub>36</sub> over a period of 20 days, according to the manufacturer. However, in this study the positive and the negative discrepancy were observed between the actual and that indicated by the manufacturer for C<sub>32</sub> and C<sub>36</sub>, respectively. No significant seasonal and sex effects were found in the actual release rate of CRC. These results were similar to our previous research on cashmere goat grazing on native *L. chinensis* community (Sun et al., 2008).

Since the introduced grassland had only one kind of forage, diet selection was limited, therefore, the intake was the essential factor affecting nutritional status of grazing animals. Malnutrition, resulting from inadequate or unbalanced nutrients intake, would reduce animal performance and feed efficiency. In this study, wethers and does had the highest daily DM intake of 1267.5 and 912.4 g per animal (91.91 and 86.73 g/kg LW<sup>0.75</sup>) in summer, respectively, when the *L. chinensis* had a higher nutrients content, palatability, and adequacy. The inadequacy of pasture in spring and the decrease of nutritive value and palatability of *L. chinensis* in autumn and winter contributed to the similar lower level of DM intake of both wethers and does in spring and autumn. The lowest daily DMI of wethers and does was 897.6 and 667.9 g per goat (65.24 and 62.71 g/kg LW<sup>0.75</sup>), respectively, in winter. All of these values are similar or higher than the maintenance plus 25% to 50% activity requirement of 600 to 720 g (20 kg body weight) and 810 to 980g DM (30 kg body weight) recommended by NRC (1981). By contrast, the data, obtained in the same year and pasture by Sun and Zhou (2007), indicated the sheep got the higher DM intake of 91.4 and 119.2 g/kg LW<sup>0.75</sup> in spring and summer, the lower DM intake of 58 to 59 g/kg LW<sup>0.75</sup> in autumn and winter. These differences suggested clearly that the goat has more resistance and adaptability to low quality forage than sheep.

The NRC (1981) recommends that the requirement of ME maintenance plus 25% to 50% activity for a grazing goat varies from 0.53 to 0.64 MJ/kg LW<sup>0.75</sup>, and the protein requirement was 4.8 to 5.8 g/kg LW<sup>0.75</sup>. Compared with the requirement for grazing goats, both the ME and CP intakes were sufficient and with the balance energy:nitrogen ratio in spring and summer, to meet the requirement. However, the ME intake decreased to the maintenance level in autumn, and 0.78 maintenance in winter and the ME deficiency would be more severe when the cold stress was considered. CP intake decreased more seriously than the ME intake during the seasons with withered grass, the CP intakes were only approximate 0.5 and 0.3 maintenance requirement during the autumn and winter, respectively. Consequently, energy:nitrogen ratio of diets was also out of balance and further aggravated the malnutrition of goats grazing on the introduced *L. chinensis* pasture. Meanwhile, autumn and winter were the pregnant and lactation periods of the goats and the cashmere was also in the rapid growth stage. These data indicated that the introduced *L. chinensis* pasture could not provide sufficient nutrients to meet the maintenance requirement, much less production and reproduction requirement. Protein and energy supplements were necessary to overcome this problem, and the introduction of some legume species into *L. chinensis* pasture also could be considered, but the plant species proportion, distribution and the community succession under the grazing would be a series of complex questions which deserves further studies.

With the decrease of CP and the increase of ADF and NDF in the diet of grazing goats, DM digestibility decreased gradually, which indicated a negative relation between the DM digestibility and the maturity of forage. These results were in accord with the relationship between the growth period of cool season and tropic grass and digestibility reported by Corbett (1969). Similar results were obtained by Sun and Zhou (2007) when comparing the seasonal change of *L. chinensis* digestibility of sheep grazing on the same pasture at the same time.

## CONCLUSIONS

The results obtained in the present study indicate that differences of CP and cell wall constituents between the plant parts selected by goats and the whole plant *L. chinensis* mean that it is not accurate to evaluate the nutritional status of grazing goats using the whole plant represent the diet. The grazing goats experienced the relative sufficient nutrients supply in spring and summer, and a severe CP and ME deficiency in winter with differences in feed intake and digestibility among them. The CP is the first limiting nutrient. Furthermore, the sex of the goat seemed to have exerted a certain influence on feed

intake, and there were some interactions of season and sex on some nutrients intake.

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