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Seasonal Changes in Voluntary Intake and Digestibility by Sheep Grazing Introduced *Leymus chinensis* Pasture

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ABSTRACT : A study was conducted to investigate the seasonal changes in nutrient composition of pasture, voluntary intake and digestibility of sheep grazing an introduced *Leymus chinensis* pasture located in western Jilin Province, China. The whole-plant of *L. chinensis* and the samples simulating ingestion by sheep (simulating sample) were collected in spring (May, 2004), summer (July, 2004), autumn (September, 2004) and the end of winter (April, 2005). The contents of gross energy (GE), organic matter (OM), crude protein (CP), neutral detergent fibre (NDF), acid detergent fibre (ADF) and alkanes were determined. Voluntary intake and apparent digestibility of the nutrients in each season were also examined using 6 mature Chinese Northeast Merino ewes (differed among the seasons) grazing on a paddock of 1 ha size. The apparent digestibilities of GE, dry matter (DM), OM, CP, NDF and ADF of *L. chinensis* were significantly greater ($p<0.05$) in spring and summer than in autumn and winter. Metabolizable energy (ME) content was 12.13, 11.62, 8.66 and 10.40 MJ/kg DM for *L. chinensis* in spring, summer, autumn and winter respectively, and the corresponding voluntary feed intakes were 91, 119, 59 and 58 g/d per kg metabolic weight ($LW^{0.75}$). The ME contents and DM intakes in autumn and winter were significantly lower than in spring and summer ($p<0.05$). The intake of *L. chinensis* pasture was sufficient to provide ME requirements for maintenance by the dry ewes in all the seasons, but inadequate for maintenance protein requirement in winter. (Supported by funds from National Basic Research Program of China, Grant No. 2007CB106800). (**Key Words :** *Leymus chinensis,* Sheep, Voluntary Intake, Digestibility)

INTRODUCTION

Leymus chinensis (Trin.) 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 (Li, 1988; Xiao et al., 1995). The high palatability and yield of *L. chinensis* makes it an ideal species for both grazing and hay production (Li, 1988; Wang et al., 1997). The grass is highly tolerant to arid, saline, alkaline and low fertility conditions (Koyama, 1987; Huang et al., 2002), and *L. chinensis* has very long and strong rhizomes and vigorous vegetative propagation, giving rise to extensively spreading clones and often forming monodominant stands. These characteristics make it ready for establishment or renewal of introduced grassland (Chen et al., 1988). Songnen grassland has been grazed by nomadic herds for centuries (Zhao et al., 1990); it has been degraded in both pasture quality and productivity by overstocking of domestic animals. This lead to a dramatic reduction of pasture available for the grassland livestock industry. To solve this problem, *L. chinensis* pasture has been introduced and widely established particularly in the northeast of China to improve livestock production and sustainability of ecological environments.

For an introduced pasture in a local livestock system, it is essential to know its nutritive value to animals, particularly the digestibility of nutrients, the efficiency of nutrient utilisation and voluntary intake (Coleman et al., 2002). In addition to chemical composition, nutritive values are the result of the processes of digestion and metabolism by animals, and form a basis for integration of the pasture into the local ecosystem. A lack of understanding of the nutritive value of *L. chinensis* pasture for sheep, particularly in a grazing condition in various seasons, has impeded progress towards developing an appropriate sheep grazing system in the northeast of China.

The nutritive value of *L. chinensis* hay has been studied for sheep (Zai et al., 1994; Lou et al., 2006), while

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knowledge of the seasonal changes in the pasture for grazing animals is rather limited. The botanical and chemical compositions and nutritive values of *L. chinensis* pasture vary with the seasons. The dietary selection of the pasture and voluntary intake by grazing animals also fluctuate among the seasons. Therefore, it is essential to determine these seasonal alterations, and thus strategic management systems can be established for an efficient use of pasture for the sheep industry.

The objective of this study was to determine the herbage intake and digestibility of nutrients. The intakes of ME and CP were also compared with the requirements of Chinese Northeast Merino sheep, grazing on a perennial *L. chinensis* pasture during the four seasons.

MATERIALS AND METHODS

Location of the pasture and climate

The study was conducted on an introduced *L. chinensis* pasture located near the Grassland Ecology Field Station (44° 41' N, 123° 45' E) of the Northeast Normal University, Jilin Province, China.

The main characteristics of the climate in this region are cold, dry and frequently windy in spring, a warm, wet summer with frequent droughts, early autumn frosts, and a long cold winter sometimes with snowfalls. The mean annual air temperature is about 5°C, with monthly values ranging from -18°C in January to 23°C in July. Annual precipitation ranges from 400 to 500 mm, 80%-90% of which falls between May and September. This study was carried out from 20 May 2004 to 19 April 2005.

Pasture

The characteristic of the introduced pasture is a homogeneous vegetation type with nearly 100% of *L. chinensis*. The pasture turns green at the end of April, and reaches maximum above-ground biomass in mid-August or early September. The biomass of *L. chinensis* begins to decline in September and ceases to grow in early October (Li et al., 1988).

Experimental design and pasture sampling

One ha of perennial *L. chinensis* pasture was used for this study. The pasture was sown in August 2003, and used for grazing sheep from May, 2004 to April, 2005. Four groups of mature, dry Chinese Northeast Merino ewes, each group with 6 ewes, were used in four seasons. The live weight of the ewes in the four groups averaged 33.2, 40.8, 45.5 and 39.8 kg, respectively. Voluntary intake and digestibility in grazing sheep were determined respectively in spring (May 30 to June 14, 2004), summer (July 30 to August 14, 2004), autumn (September 30 to October 14, 2004) and the end of winter (referred to as winter in the following text, April 5 to April 19, 2005). All sheep were shorn, drenched with Ivermectin and injected subcutaneously with 500,000 IU vitamin A, 75,000 IU vitamin D and 50 IU vitamin E prior to grazing on the pasture.

During each season, C_{32}/C_{36} Captec alkane controlled release capsules (CRC, Fernz Health and Science, NZ), designed for sheep weighing 30 to 50 kg, were dosed to each ewe. The capsule was designed to release 50 mg C_{32} and 50 mg C_{36} per day for approximately 20 days. The equilibrium of the alkanes in the rumen was achieved within seven days of dosing according to the product instruction. Daily rectal fecal samples were collected from day 8 until day 15 after dosing. All the samples were taken in the morning, and stored at -20°C. The samples of herbage were taken daily both as the whole-plant and as simulating samples. To collect the simulating samples, grazing patterns were closely examined focused on the high part of plant for 30 min and samples were taken from the same area grazed by sheep. The simulating samples were collected consecutively for 7 days, twice a day. All the samples were stored at -20°C.

At the end of the sampling period, the daily samples of herbage and feces were pooled, freeze-dried and ground to pass through a 1-mm screen, and stored at room temperature for alkane and nutrient analysis.

Alkane analysis

Alkane was determined according to the method of Mayes et al. (1986), Premaratne et al. (2005) and some modification. Briefly, 2 g *L. chinensis* or 1 g fecal sample was weighed into a pyrex bottle with three replicates; two internal standards (2 mg C_{22}, 2 mg C_{34}) and 15 ml ethanolic KOH were added to each sample. The tubes were capped tightly and heated for 4.5 h at 90°C. The extraction of alkanes was performed by adding 7 ml heptane plus 5 ml distilled water, ultrasonic treatment for 5 min, followed by transferring the heptane layer to an evaporating dish. The extraction was repeated twice with 5 ml hexane. The evaporating dish was heated in a water bath at 60°C and the heptane solution was evaporated to approximately 1 ml. The solution was then transferred onto a silica gel column (70-230 mesh), and the dish was rinsed twice with 3 ml heptane. The lipid in the sample was absorbed into the gel, and alkanes were eluted. The eluate was collected in an evaporating dish, dried in a water bath at 60°C, and reconstituted in 1 ml heptane for determination of alkane concentrations.

The identification of alkanes was determined using a Shimadzu gas chromatograph/mass spectrometer (Q5050A GCMS, Shimadzu Company, Japan). The concentrations

Table 1. Chemical composition (g/kg DM), *in vitro* DMD and alkane concentrations* (mg/kg DM) of whole-plant of *L. chinensis* and the simulating samples

	Whole-plant				Simulating samples			
	Spring	Summer	Autumn	Winter	Spring	Summer	Autumn	Winter
GE (MJ/kg)	22.33	19.86	21.59	20.09	19.96	18.12	19.66	21.40
OM	935	946	959	951	949	949	950	947
CP	106.0	95.2	23.9	28.0	98.6	107.5	46.9	23.5
ADF	324	329	435	490	329	329	385	435
NDF	600	644	809	780	718	718	780	707
In vitro DMD	0.52	0.58	0.52	0.41	0.59	0.63	0.55	0.45
C_{25}	19.60	19.34	19.21	55.19	59.80	6.84	15.46	26.67
C_{27}	37.05	22.49	33.99	74.69	91.33	12.01	42.28	61.09
C_{29}	64.33	39.54	63.52	145.97	71.81	30.46	98.67	112.92
C_{31}	200.36	102.09	251.96	273.23	150.34	93.25	287.02	297.61
C_{33}	47.81	94.44	34.27	22.67	31.19	20.68	43.70	118.12

* $C_{25,}$ pentacosane; $C_{27,}$ heptacosane; $C_{29,}$ nonacosane; $C_{31,}$ hentriacontane; $C_{33,}$ tritriacontane.

were analyzed using a Shimadzu GC2010 equipped with a flame ionization detector (Shimadzu Company, Japan). A capillary column, DB-1, 30 m×0.25 mm×0.25 μm was used. Helium was the carrier gas. The initial column temperature was set at 200°C, held for 0.04 min, then increased to 275°C at a rate of 30°C/min. Flame ionization detector temperature was 280°C. One μl of the reconstitute was injected at split mode. Individual alkanes were identified from their retention times, and quantitated according to their peak areas in reference to the internal standard C_{34} (tetratriacontane).

Nutrient analysis

Herbage and fecal samples were analyzed for gross energy (GE), crude protein (CP), organic matter (OM), acid detergent fibre (ADF) and neutral detergent fibre (NDF). The contents of GE, OM, CP were determined according to the techniques described by AOAC (1990). NDF and ADF were determined by the method of Van Soest et al. (1991); the samples were not treated with amylase and the residues were not corrected for residual ash. Organic matter was determined as the difference between dry matter (DM) at 105°C and ash at 550°C. *In vitro* DM digestibility (DMD) was determined using the method of Tilley and Terry (1963).

Calculations

Daily DM intake (DMI) and digestibility for individual sheep were calculated using the dosages of the alkanes, and concentrations of alkanes in the simulating samples of the pasture and fecal samples based on the method of Dove et al. (1991). Briefly, DMI was calculated using a formula as follows:

$$\text{DMI (kg DM/day)} = (D_{32}\times F_{31}/F_{32})/(H_{31}-(F_{31}/F_{32})\times H_{32}) \quad (1)$$

Where D_{32} is the amount (mg/day) of alkane (C_{32}) released from the CRC, F_{32} and H_{32} are the corresponding concentrations (mg/kg DM) of C_{32} in the fecal and herbage samples, and F_{31} and H_{31} are the concentrations (mg/kg DM) of the natural C_{31} alkanes in feces and herbage, respectively. The C_{31} alkane was selected because its concentration was the highest in *L. chinensis*.

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

$$\text{DMD} = 1-((D_{36}+\text{DMI}\times H_{36})/F_{36})/\text{DMI} \quad (2)$$

Where D_{36} is the amount (mg/day) of alkane (C_{36}) released from the CRC; H_{36} is C_{36} alkane concentration in *L. chinensis*, and was too low to be detected by the GC method. Therefore, zero was used for H_{36}. F_{36} is C_{36} alkane concentration in feces.

The daily intake was then calculated as DMI per kg of metabolic live weight ($LW^{0.75}$) in order to compare the seasonal variations as the live weight of the sheep varied significantly. The live weight of the sheep at the end of each seasonal period was used in the calculations.

Intakes and digestibilites of GE, OM, CP, NDF and ADF were calculated based on DMI (MJ or g/d), their concentrations (g/kg DM) in the pasture (simulating pasture samples) and fecal samples, and calculated excretions (g/d) from the fecal output which was calculated from Formula 2 (ie, D_{36}/F_{36}). Digestible energy content (DE) of the pasture was calculated as the difference between gross energy intake (DMI×gross energy content) and the faecal energy (faecal output×energy content in faeces). Metabolizable energy content was then calculated as 0.82 DE (NRC, 1985).

Statistical analysis

The data are presented as means and standard error of means (SEM) unless otherwise stated. The differences among the seasons were examined using one-way analysis of variance (ANOVA) procedure, and the analysis was

Table 2. Metabolizable energy content and nutrient digestibility of *L. chinensis* pasture for sheep (n = 6)

	Spring	Summer	Autumn	Winter	SEM
ME/DM (MJ/kg)	12.13^{a}	11.62^{a}	8.66^{c}	10.40^{b}	0.404
Digestibility (%)					
DM	73^{a}	77^{a}	54^{b}	50^{b}	2.4
GE	74^{a}	78^{a}	54^{b}	59^{b}	2.5
OM	74^{a}	80^{a}	54^{b}	54^{b}	2.2
CP	78^{a}	82^{a}	33^{b}	-32^{c}	5.1
NDF	76^{a}	77^{a}	63^{b}	54^{b}	3.4
ADF	69^{a}	72^{a}	53^{b}	47^{b}	2.7

Values on the same row with different superscripts differ significantly ($p<0.05$).

performed using computing software GenStat 8.0 (VSN International Ltd, Herts, UK).

RESULTS

Chemical composition and alkane pattern of *L. chinensis*

The chemical composition and alkane concentration of the whole-plant *L. chinensis* and of simulating samples in four seasons are shown in Table 1. Crude protein concentrations were greater in spring and summer and the lowest (<30 g/kg DM) in winter. The concentrations of ADF and NDF were increased from spring, summer to autumn and winter, when the pasture changed from growth period to maturity stage. *In vitro* DM digestibility (IVDMD) of *L. chinensis* ranged from 0.41 in winter to 0.63 in summer.

The differences in chemical composition between the whole-plant and simulating samples varied among seasons. Compared with the whole-plant sample, the concentrations of CP and ADF in simulating samples were similar in spring and summer, but CP was higher in autumn and ADF was lower in autumn and winter. *In vitro* DM digestibility was consistently higher for the simulating samples than for the whole-plant.

C_{31} was the most abundant alkane in *L. chinensis*, followed by C_{29} and C_{33}. C_{36} concentration was not detectable, while only a trace level of C_{35} could be detected.

Energy value and apparent digestibility of nutrients of *L. chinensis*

Metabolizable energy content, apparent digestibility of DM, GE, OM, CP, NDF and ADF of *L. chinensis* are shown in Table 2. Seasonal differences in nutrient concentrations and digestibility of *L. chinensis* were observed. Metabolizable energy content and digestibility of DM, GE, OM, CP, NDF and ADF were significantly greater ($p<0.05$) in spring and summer than in winter and autumn, and in winter plants had greater metabolizable energy content and lower digestibility of CP than in autumn. However, digestibility of DM, GE, OM, NDF and ADF were similar between autumn and winter ($p>0.05$). All the values in spring and summer were similar ($p>0.05$). The apparent digestibility of CP in winter was negative due to fecal excretion of nitrogen exceeding intake.

Nutrient intake of sheep grazing on *L. chinensis* pasture

The highest voluntary intake of DM by the sheep grazing on *L. chinensis* pasture was 1,868 g/d in summer (Table 3), which was significantly higher than in the other three seasons ($p<0.05$). Trends for OM, NDF and ADF were similar to that for DM. The intakes of ME and digested CP were significantly higher ($p<0.05$) in summer than in spring, and their intakes in spring and summer were significantly higher ($p<0.05$) than in both autumn and winter.

The daily intakes were affected, to some extent, by the size of the sheep, which differed amongst seasons. While the intakes of sheep were calculated per kg metabolic live weight ($LW^{0.75}$), the highest DM intakes were also found in summer. For digested CP and NDF, the values in summer were greater than those in spring ($p<0.05$). There were also no significant differences in intake of the nutrients between autumn and winter ($p>0.05$), and also no significant

Table 3. Nutrient intakes of ewes grazing on introduced *L. chinensis* pasture (n = 6)

	Spring	Summer	Autumn	Winter	SEM
DM (g/d)	1,267^{b}	1,868^{a}	1,051^{b}	911^{b}	129.9
OM (g/d)	1,203^{b}	1,773^{a}	998^{b}	865^{b}	123.3
NDF (g/d)	910^{b}	1,340^{a}	820^{b}	643^{b}	93.9
ADF (g/d)	417^{b}	614^{a}	405^{b}	396^{b}	136.1
Digested protein (g/d)	95.8^{b}	170.9^{a}	17.4^{c}	-6.2^{c}	35.2
ME (MJ/d)	15.3^{b}	22.7^{a}	9.3^{c}	9.6^{c}	1.8
per kg metabolic weight ($LW^{0.75}$)					
DM (g/d)	91.4^{a}	119.2^{a}	59.0^{b}	57.7^{b}	9.44
OM (g/d)	86.7^{a}	113.2^{a}	56.0^{b}	54.8^{b}	8.96
NDF (g/d)	65.6^{b}	85.6^{a}	46.0^{bc}	40.7^{c}	6.81
ADF (g/d)	30.1^{ab}	39.2^{a}	22.7^{b}	25.1^{b}	3.22
Digested protein (g/d)	6.91^{b}	10.93^{a}	0.97^{c}	-0.40^{c}	2.66
ME (MJ/d)	1.10^{a}	1.45^{a}	0.52^{b}	0.61^{b}	0.13

Values on the same row with different superscripts differ significantly ($p<0.05$).

differences in NDF and ADF intakes between spring and autumn ($p>0.05$), whereas the intakes of DM, OM, ME and digested CP were higher in spring than in autumn ($p<0.05$).

The daily CP intakes, calculated from CP concentrations in the simulating samples and daily DM intake, averaged 125, 201, 49 and 21 g/d for spring, summer, autumn and winter, respectively. The intake of 21 g/d in winter was lower than the N excreted in the feces, which resulted in a net N loss of 0.4 g/d kg $LW^{0.75}$ from the digestive tract.

DISCUSSION

Seasonal changes in nutritive value of *L. chinensis*

The contents of CP, NDF and ADF in *L. chinensis* were significantly different amongst seasons, but not so for OM and GE. Similar findings were reported by other researchers (Ding et al., 1999; Wang et al., 2005). The change in nutrient composition with season may be attributed to the effect of advancing plant maturity which is associated with a decrease in leafiness and an increase in the stem: leaf ratio, changes in the composition of the cell wall (Akin et al., 1977) and a loss of cell contents (Ballard et al., 1990). This leads to not only changes in the proportion of plant parts, but also in chemical characteristics. The change in chemical composition may also be related to higher temperature in the summer of Northeast China. High temperature usually promotes the accumulation of structural material (i.e. cell-wall material) and also increases metabolic activity, which decreases the pool size of cell contents. Henry et al. (2000) reported that when vegetative pasture species grew in temperatures between 14°C and 34°C, the lignin, cellulose and hemicellulose contents of *Lolium multiflorum* (Italian ryegrass) increased markedly with increasing temperature and this was associated with a lower *in vitro* dry matter digestibility. This change happens in C_3 but not in C_4 grasses (Ford et al., 1979).

From the results, ME contents for *L. chinensis* changed among the four seasons, and varied from 8.66 to 12.13 MJ/kg, with the highest ME content in spring and summer and the lowest concentration in autumn. This data was similar to the results of Lou et al. (2006) who reported a ME value of 8.12 MJ/kg for *L. chinensis* hay harvested in autumn. The OM digestibility of the *L. chinensis* pasture from this study ranged from 54% to 80%, which is comparable with the values reported by Minson and McLeod (1970) for a number of tropical and subtropical grass species. Zai et al. (1994) and Lou et al. (2006) reported a DM digestibility of 50% for *L. chinensis* hay, from an in-door trial, which is similar to our results in autumn and winter. However, more attention should be paid to the results of apparent digestibities of nutrients, which could be confounded by variations in DM intake because a low intake will result in an under-estimation of apparent digestibility. This could be another factor contributing to the low digestibilities found in autumn and winter in this experiment.

Leymus chinensis pasture reaches the senescent stage in early October (Li et al., 1988). The quality of the pasture in autumn determined in this experiment was similar to that in winter. The higher ME content of *L. chinensis* in winter than in autumn was probably due to an adaptation of the animals to the season and availability of feeds. Sheep, like all ungulates, have evolved a range of responses to cope with such seasonal variety which buffer the effects of such changes on nutrient intake (O'Reagain et al., 1995). Animals may adjust foraging behaviour or increase the time on chewing and ruminating to improve the extent or rate of digestion (ie, digestibility) of low-quality food in order to compensate for reduced availability (Allden et al., 1970).

There was a discrepancy in the data pertaining to the 'simulating sample' in spring, in which NDF concentration was higher and N concentration was lower than the whole-plant samples. This might be due to presence of dead forage in simulating samples. Although the pasture was sown during the previous autumn, some dead and dried forage remained in the following spring and summer, and decomposition happened in the late summer. The dried and dead forage contains a high concentration of NDF and a low concentration of N. We observed that the sheep unavoidably consumed some dead forage when they ingested fresh *L. chinensis*.

Constraints on voluntary intake by sheep grazing on *L. chinensis* pasture

Voluntary intake is another important parameter for estimating forage quality and animal performance (Minson, 1990; Coleman et al., 1999). In this study, DMI of sheep reached peak values of 91.4 and 119.2 g/kg $LW^{0.75}$ per day in spring and summer, respectively. These values are similar to or slightly higher than the voluntary feed intake of 90.5 g/kg $LW^{0.75}$ for 85 fine diets containing 48% concentrates (ARC, 1984). By contrast, in autumn and winter the grazing intakes were reduced to 58-59 g/kg $LW^{0.75}$ per day, halved when compared with those in summer. These values are very close to the intake of 57 g/kg $LW^{0.75}$ averaged for 107 coarse diets (ARC, 1984). Clearly, this low feed intake could limit the performance of animals. Low feed intake might result from inadequacy of pasture on the paddock, or from deteriorated quality of the pasture that limits the intake. Zhang (2004) reported that the voluntary intake of sheep that were fed *L. chinensis* hay in an animal house was 62.5 g/kg $LW^{0.75}$ per day. The similarity of the grazing intakes in autumn and winter obtained from this experiment to voluntary feed intake reported by Zhang et al. (2004) indicates that the quality of *L. chinensis* pasture determines the low grazing intake in autumn and winter, and the availability of the pasture may have least impact.

It is a common feature in most grazing systems that the intake of herbage by sheep is restricted for much of the year (Weston, 2002). Poppi et al. (1987) reported that canopy height and mass are two main factors affecting intake of grazing livestock, but when both of them are optimal, the nutritional factors of forage become the primary constraint. Penning et al. (1991) demonstrated that daily herbage intake was constant with sward height of 6 cm and above, i.e., sward height of 6 cm seems to be a threshold of restriction to grazing intake. During this study, the canopy of *L. chinensis* pasture in spring was always higher than 10 cm. The heights in the other seasons were even greater. These observations suggest that nutritional factors rather than the pasture availability could be a major factor contributing to the low grazing intake in autumn and winter.

Nitrogen content and cell wall constituents are important factors which determine feed intake. The former has a significant influence on microbial activity in the rumen, and the latter affects the outflow rate of rumen contents (Weston, 2002). ARC (1980) states that rumen microbes require 30 g of N from dietary sources per kg of OM apparently degraded for efficient rumen microbial activity and growth. When N content per kg digestible OM is less than 16-19 g, feed intake is often reduced (Weston, 2002). In the current study, the N content per kg of apparently digested OM averaged 22, 23, 15 and 7 g in spring, summer, autumn and winter, respectively. Obviously, the insufficiency of N from *L. chinensis* pasture, particularly in winter and autumn, is a main reason for the low intakes. Weston (1996) reported the level and properties of herbage fibre could constrain the clearance of digesta from the rumen, thereby resulting in digesta accumulation in the rumen and generating satiety signals by rumen mechanoreceptors. Sunagawa (2007) demonstrated that feeding induced hypovolemia is one of the factors depressing feed intake in goats fed on dry forage. These might be other reasons for the low intake which happened in autumn and winter when the forage was dry and high in NDF and ADF.

Seasonal nutrient intake comparison with nutrient requirements of grazing sheep

For dry ewes, feed intake should match at least the maintenance requirement of ME (MEm). The NRC (1981) recommends a daily MEm of 0.389 MJ/kg LW$^{0.75}$ and an additional 15% of MEm is required to support grazing activity. However, SCA (1990) recommends that an increase of 40-50% in the MEm for a housed animal is required for a grazing animal in the absence of cold stress. Therefore, MEm for a grazing sheep varies from 0.447 to 0.584 MJ/kg LW$^{0.75}$. A MEm of 0.45 MJ/kg LW$^{0.75}$ for grazing Chinese Merino ewes was reported by Feng et al. (1997). Compared with the maintenance requirement for sheep, the ME intakes of *L. chinensis* pasture, ranged from 0.52 MJ/kg LW$^{0.75}$ in autumn to 1.45 MJ/kg LW$^{0.75}$ in summer in this study, which was sufficient, to meet maintenance requirement.

As for the protein requirement for maintenance, NRC (1981) recommends a value of 2.03 g of crude protein per kg LW$^{0.75}$. Grazing activity does not use any additional dietary protein (NRC, 1981). Our measurements showed that the daily intake of crude protein from *L. chinensis* pasture averaged 8.96, 12.81, 2.62 and 1.35 g/kg LW$^{0.75}$ for spring, summer, autumn and winter respectively. The intake in autumn was close to the maintenance requirement, and in winter it was below the requirement. This indicates that intake of *L. chinensis* pasture in winter does not provide sufficient protein to meet the maintenance requirement of ewes. Pregnancy and then lactation of Chinese Merino ewes occurs in winter, which demands a very high level of protein supply (ARC, 1984). If ewes are grazed on *L. chinensis* pasture, they could suffer from serious protein deficiency. Therefore, protein supplementation is essential to a *L. chinensis* pasture-based grazing system.

For a better use of both energy and N by sheep, a proper N: energy ratio in pasture or diet is critical. Egan (1977) and Kempton (1979) suggested that the ratio of protein (N×6.25) apparently absorbed from the small intestines to ME intake under maintenance conditions should be 6.5 g/MJ (6.5:1). This ratio should be increased to 12:1 for maximum wool production, and further up to 14:l for reproductive ewes in late pregnancy and early lactation (Kempton, 1979). For the *L. chinensis* pasture, the ratio varied from -0.64:1 in winter to 7.5:1 in summer. This indicates that *L. chinensis* pasture is high in energy but low in N content. This problem could be overcome by introduction of a legume species into *L. chinensis* pasture, which deserves further studies.

In conclusion, *L. chinensis* pasture exhibited substantial seasonal variations in ME and CP content, and DM intake by grazing sheep. *L. chinensis* pasture contained relatively high level of energy. Due to its lower content in winter, CP is the first limiting nutrient. The dry ewes suffered from protein deficiency, unable to meet their maintenance requirement in winter. This problem could be more severe in reproductive ewes which require more protein. Provision of more protein either with supplementation of protein feeds or with an introduction of legume species is recommended for a *L. chinensis* pasture-based grazing system.

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