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Forage Nutrition of Range Grasses Growing in Northeastern Mexico

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Introduction

There are many advantages of native grass species because they are drought-resistant and require low input costs. These characteristics make them very suitable for inclusion in a balanced and sustainable grazing system, particularly in low rainfall areas. Moreover, many native grasses are well adapted to surviving the heat and lack of moisture typical of many areas of northeastern Mexico and South Texas, U.S. (Ramirez *et al*., 2004). These characteristics include special growth characteristics, such as thickened stems at the base for food storage and a corky integument over the roots to protect them against excessive heat. Some species have a different leaf structure from those species adapted to the higher rainfall areas. This leaf structure gives the plant small, thickened leaves or bristle-like leaves that help to reduce the amount of moisture that is transpired from the leaf surfaces. However, high levels of ash in most of the native grasses indicate the presence of high amounts of silica which may reduce digestibility (Van Soest, 1994).

The quality of range grasses is correlated with season and plant phenology. There are usually parts of each year when the nutritional value of vegetation is high and low. Typically, plants are of highest quality during their growing season. However, within the growing season there may be significant differences in nutritional quality between early-and late-growing season (Martin-Rivera and Ibarra-Flores, 1989). Mature vegetation has a higher proportion of cell walls to cell contents and is less nutritious than young vegetation. During the early growth stages range grasses are highly digestible; however, decline rapidly as the season advances (Ramirez et al., 2004). Once into the dormant season, grasses lose quality as soluble cell contents are leached from the plants by precipitation. Matching of livestock nutritional requirements with the optimum season for nutritional quality from the range grasses is an important element of livestock production systems. For example, grasses cure well, particularly in semiarid and arid climates, and stand as an excellent source of energy during their dormant season (Van Soest, 1994).

Rhynchelytrum repens and *Cenchrus ciliaris* are cultivated species that were introduced to Mexico with good adaptation. Moreover, *Cenchrus ciliaris* because its wide distribution to these semiarid regions it has been considered as a naturalized grass. In addition, it has been mentioned as a south Texas and northeastern Mexico wonder grass (Hanselka, 1988); however, seasonality of rainfall and temperature are major influences on nutritional quality (Ramirez *et al*., 2003a).

The objectives of this study were to determine and compare seasonally the chemical composition and the rate and extent of digestion of dry matter and crude protein of the forage from two cultivated and thirteen native grasses growing in northeastern Mexico.

Materials and Methods

The study was carried out at the "Sauces Ranch" of about 900 ha located in General Terán County of the state of Nuevo León, México. It is located at 25°24´26´´ west longitude and 99°46´33´´ north latitude, with an altitude of 272 m. The climate is typically subtropical and semi-arid with a warm summer. Mean monthly air temperature ranges from 14.7°C in January to 22.3°C in August, although daily high temperatures of 45°C are common during the summer. Peak rainfall months are May, June and September. Annual rainfall during the year of study was about 360 mm distributed as follows; 25 mm in winter, 32 mm in spring, 238 mm in summer and 65 mm in autumn. The main type of vegetation is known as the Tamaulipan Thornscrub or Subtropical Thornscrub Woodlands (SPP–INEGI, 1986). The dominant soils are deep, dark-gray, lime-gray, lime-clay Vertisoles, with montmorillonite, which shrink and swell noticeably in response to changes in soil moisture content. They are characterized by high clay and calcium carbonate contents, pH varied from 7.5 to 8.5 and low organic matter content (Foroughbakhch, 1992).

Grasses such as *Bouteloua curtipendula* (Gould & Kapadia), *Bouteloua trífida* (Thurber), *Brachiaria fasciculata* (Sw.), *Digitaria insularis* (L.), *Chloris ciliata* (Swartz.), *Leptochloa filiformis* (Lam.) Beauv, *Panicum hallii* (Vasey.), *Panicum obtusum* (H.B.K.), Parodi., *Paspalum unispicatum* (L.), *Setaria macrostachya* (H.B.K.), *Setaria grisebachii* (Fourn.), *Tridens eragrostoides* (Vasey & Scribn.) Nash, *Tridens muticus* (Torr.) Wash. And the cultivated *Cenchrus ciliaris* (L.) and *Rhynchelytrum repens* (Willd.) Hubb, were collected for nutritional studies because they represent and important source of forage for grazing ruminants in northeastern Mexico (Ramírez *et al*., 1999). In this study, *C. ciliaris* has been considered as reference grass of good nutritional quality. Collection of grasses was made during the four seasons beginning in autumn of 2001 (October 20), followed by winter of 2002 (January 21), spring of 2002 (April 28) and summer of 2002 (July 23). As encountered in four sites, randomly located in all ranch, grasses were hand harvested until adequate amounts of material were obtained, and compositing by species in each site and in each season. Samples were stored in paper bags in the field and transported to laboratory. The sites of collection were grazed by livestock. Partial dry matter was determined subjecting samples to oven at 55° C during 72 h, then were ground in a Wiley mill (1 mm) and stored in plastic containers for further analyses.

In each season, by quadruplicate, samples were analyzed for DM, organic matter, CP, Neutral detergent fiber (NDF) and acid detergent lignin (ADL; Van Soest *et al*., 1991). The rate and extent of DM loss was estimated using the nylon bag technique. Four rumen cannulated Pelibuey x Rambouillet sheep (weighing 45 ± 3.5 kg, BW) were used to incubate the nylon bags (5 x 10 cm, 53 μm of pore size), which contained ground (4 g) samples of each grass species. During the trial, sheep were fed alfalfa hay *ad libitum*. Incubation periods were at 4, 8, 12, 24, 36 and 48 h. Upon removal from the rumen, bags were washed in cold water. Zero time disappearance was obtained by washing unincubated bags in similar fashion, and then bags were dried at 55° C in an oven for 48-h. Disappearance of DM for each incubation period was calculated by:

DM disappearance, % = (Initial weight-final weight)/(initial weight) x 100

Digestion characteristics of DM were calculated using the equation of ∅rskov and McDonald (1979):

$$p = a+b\,(1-e^{-ct})$$

Where:
p is disappearance rate of DM at time **t**,
a is an intercept representing the portion of DM solubilized at the beginning of incubation (time 0),
b is the portion of DM that is slowly degraded in the rumen,
c is the rate constant of disappearance of fraction **b** and
t is the time of incubation.

The nonlinear parameters **a**, **b** and **c** and effective degradability of DM (EDDM) = $(\mathbf{a}+\mathbf{b})\mathbf{c}/(\mathbf{c}+\mathbf{k})(\mathbf{e}^{-(ct)LT})$, were calculated using the Neway computer program (McDonald, 1981); **k** is the estimated rate of rumen out flow and **LT** is the time lag. The EDDM of samples were estimated assuming a rumen out flow rate of 2 % h^{-1}.

Metabolizable energy content was estimated by the *in vitro* gas production technique, in which 200 mg sample of each grass was incubating in rumen liquor *in vitro* and calculated according to Menke and Steingass, (1988) equation: ME (Mcal kg^{-1} DM) = (2.20 + 0.136 gas production at 24 h + 0.057 crude protein + 0.0029 crude fat^2)/4.184. Metabolizable protein content was determined using the PDI system principles (Verite *et al*. 1987). Main variables used to calculate the metabolizable protein content were: CP content, effective degradability of CP, *in vitro* OM digestibility (Daisy II ANKOM Technology, Macedon NY USA), forage fat content and organic matter fermented in the rumen. It was assumed that intestinal protein digestibility of bypass protein varied from 0.65 to 0.75.

Data were statistically analyzed using an experimental design of two ways of classification (being grasses and seasons the study factors), with interaction between seasons and grasses. The interaction seasons x grasses was significant ($P<0.05$), thus analyses of variance were carried out among seasons and among grasses within seasons. (Steel and Torrie, 1980).

Results and Discussion

The CP content in all grasses was significantly different among seasons and among grasses within seasons. *B. fasciculate, C. ciliate, P. obtusum and S. grisebachii* had higher content and *R. repens* was lower (Table 1). Most of the grasses had CP values higher than *C. ciliaris*. All of the grasses exhibited their most rapid increase in CP content in summer and autumn seasons. These seasonal fluctuations in CP content may be induced by summer (238 mm) and autumn (65 mm) precipitations. Other studies have shown seasonal fluctuations in native grasses. Hendrichson and Briske (1997) reported that *H. berlangeri* had CP content of 13% in summer and reaches a low nearly of 2% in winter. Moreover, Dittberner and Olson (1983) showed that *B. gracilis* (aerial fresh immature) that grow in Wyoming, USA, had CP values of 11% in summer and 6% in winter when plants were in a dormant period. Studies carried out in Sonora, Mexico (Martin-Rivera and Ibarra-Flores, 1989) have reported that *B. gracilis*, *Aristida* spp. and *S. macrostachya*, during spring and summer of 1989, had CP values of 5 and 10%, 5 and 9%, 7 and 10%, respectively. Moreover, Ramirez *et al*. (2004) found that *C. ciliaris*, *P. hallii*, *B gracilis* and *S. macrostachya* had annual means of CP content higher in spring and autumn seasons. However, Huston *et al*. (1981) reported that *P. hallii* growing in Texas, USA, had CP content of 7% in both summer and autumn seasons.

The CP content in forages serves as a reliable measure of nutritional quality (Ganskoop and Bohnert, 2001). If a 7.5 % CP level is considered as an adequate forage quality threshold because it falls within the range of values suggested for maintenance of beef cattle (NRC, 2000). Thus, in this study, all grasses in most seasons can be considered of high nutritional quality for grazing ruminants. However, CP concentration in plants is influenced mainly by the supply the available N in soil and the state of maturity. Studies carried out in the same area by Ramirez *et al*. (2002), Ramirez *et al*. (2003ab) and Ramirez *et al*. (2005) reported that CP content in cultivated grasses such as *Panicum coloratum, Cenchrus cilaris*, *Cynodon dactylon* and *Dichanthium annulatum*, respectively, and in native grasses such as *Aristida longiseta, Bouteloua gracilis, P. hallii, Cenchrus incertus, Hilaria berlangeri* and *S. macrostachya* (Ramirez *et al*. 2004) markedly decline as the plant increase in maturity, possible because the relatively increase in cell wall and decrease in cytoplasm. It is possible that this effect could be manifested in winter and spring in evaluated grasses of this study, because in these seasons grasses showed the lowest CP content.

Cell wall (NDF) content in all grasses was significantly different among seasons and among grasses within seasons. *Setaria grisebachii* resulted with higher annual mean and *P. unispicatum* was lower. During winter and spring NDF was higher than in other seasons (Table 1). With exception of *B. curtipendula* and *R. repens* all grasses had cellulose concentration significantly different among seasons and among grasses within seasons.

Table 1. Seasonal and annual means of the crude protein, neutral detergent fiber, cellulose and acid detergent lignin in grasses

Grasses	CP, % DM							NDF, % DM						
	Seasons							Seasons						
	w	sp	su	f	M	SEM	Sig	w	sp	su	f	M	SEM	Sig
B. curtipendula	9	8	12	14	11	0.2	***	79	72	70	72	74	0.1	***
B. trifida	8	8	15	13	11	0.1	***	75	76	70	76	74	0.2	***
B. fasciculata	11	10	16	18	14	0.1	***	72	63	62	60	65	0.3	***
C. ciliaris	10	10	15	13	12	0.1	***	72	72	70	71	72	0.2	***
C. ciliata	12	10	18	15	14	0.1	***	71	67	65	70	68	0.04	***
D. insularis	11	7	13	13	11	0.2	***	70	75	69	75	70	0.1	***
L. filiformis	11	10	12	15	12	0.2	***	75	67	73	66	70	0.1	***
P. hallii	11	8	16	18	13	0.1	***	74	67	66	71	70	0.2	***
P. obtusum	12	13	17	15	14	0.1	***	74	65	61	66	65	0.2	***
P. unispicatum	9	9	13	13	11	0.1	***	70	69	64	67	68	0.2	***
R. repens	9	7	11	11	10	0.2	***	73	74	69	73	72	0.1	***
S. grisebachii	9	13	17	15	14	0.1	***	73	81	61	73	69	0.1	***
S. macrostachya	11	12	16	11	13	0.1	***	73	68	63	72	69	0.1	***
T. eragrostoides	12	13	17	11	13	0.1	***	73	74	70	76	73	0.1	***
T. muticus	8	8	16	12	11	0.1	***	78	72	70	76	75	0.1	***
Seasonal means	10	10	15	14	12			73	69	67	72	70		
SEM	0.1	0.1	0.2	0.1				0.4	0.3	0.5	0.6			
Significant level	***	***	***	***				***	***	***	***			

Table 1 Continued.-

	Cellulose, % DM							ADL, % DM						
B. curtipendula	29	28	28	28	28	0.3	NS	6	6	5	6	6	0.1	*
B. trifida	30	28	30	29	29	0.2	***	7	7	5	6	6	0.1	*
B. fasciculata	27	23	23	22	24	0.2	***	7	6	7	5	6	0.2	**
C. ciliaris	33	32	31	33	32	0.4	*	3	3	3	3	3	0.4	NS
C. ciliata	35	32	33	32	33	0.3	*	7	5	8	2	6	0.4	***
D. insularis	26	27	26	28	27	0.1	*	6	5	6	5	6	0.3	**
L. filiformis	37	29	25	28	25	0.2	***	5	7	6	5	6	0.4	**
P. hallii	31	28	28	28	30	0.5	**	5	6	4	3	5	0.5	***
P. obtusum	28	25	25	25	26	0.3	***	6	7	6	5	6	0.6	***
P. unispicatum	29	27	29	28	28	0.2	*	2	4	5	6	4	0.3	***
R. repens	28	27	29	28	28	0.4	NS	8	6	8	8	10	0.6	**
S. grisebachii	28	28	23	28	27	0.6	***	6	6	6	6	6	0.2	NS
S. macrostachya	28	27	25	28	27	0.8	**	6	7	6	7	7	0.6	**
T. eragrostoides	30	31	30	32	31	0.3	*	5	5	4	6	5	0.3	***
T. muticus	28	27	27	29	28	0.6	**	7	7	7	7	7	0.2	NS
Seasonal means	30	28	27	28	28			6	6	6	5	6		
SEM	0.4	03	0.5	0.4				0.2	0.2	0.2	0.1			
Significant level	***	***	***	***				**	**	**	**			

w= winter; sp= spring; su= summer; f= fall; SEM = standard error of the mean; Sig= significancy; *(P<0.05); **(P<0.01); ***(P<0.001); NS = not significant
CP = crude protein; NDF = neutral detergent fiber; ADL = acid detergent lignin.

With exception of *C. ciliaris* and *S. grisebachii*, lignin (ADL) content in all grasses was significantly different among seasons. Moreover, significant differences were found among all grasses within seasons (Table 1). *Rhynchelytrum repens* was higher and *C. ciliaris* was lower. All native grasses and *R. repens*, had lignin content, in annual mean basis, higher than *C. ciliaris*. Apparently, lignin in grasses plays an important role in the structural integrity of individual cells, tissues and organs. Moreover, the amount of lignin is positively associated with maturity of plants and this later negatively with rainfall (Hatfield *et al*., 1993); however, in this study, even though winter and spring had lower rainfall, lignin content was very similar when compared the mean of all grasses among seasons (Table 1).

The fraction of DM solublized at the beginning of incubation of grasses in the rumen of sheep (**a**), the fraction of DM that is slowly degraded in the rumen (**b**) and the rate constant of disappearance of fraction **b** were significantly different among seasons and among grasses within seasons (Table 2). The same pattern was observed in EDDM. *Cenchrus ciliaris* had higher annual mean EDDM and *B. curtipendula and B. trifida* were lower. In general, during summer and autumn EDDM was higher than other seasons. In all seasons, all native and *R. repens* grasses had lower EDDM than *C. ciliaris* (Table 2). It seems that CP content in grasses positively influenced the rumen digestion of DM, because of when CP increased also increased EDDM (r= 0.67; P<0.001). Seasonal rainfall and temperatures had the same influence (P=0.47; P<0.001; r=52; P<0.001, respectively) on EDDM. Conversely, when lignin increased (r=-0.50; P<0.001) EDDM decreased. Positive effects of CP and precipitation on EDDM in the forage of grasses have previously reported by Ganskoop and Bohnewrt (2001). They found that when CP in seven native grasses, collected in a rangeland of the Estate of Idaho, USA, and rain precipitation increased, also increased *in vitro* dry matter digestibility. These effects have also been reported in native grasses such as *B. gracilis*, *P. hallii*, and *S. macrostachya* growing in northeastern Mexico (Ramirez *et al*., 2004).

The ME content in all grasses was significantly different among seasons (P<0.01). Differences among grasses within seasons were also registered except for *C. ciliata* and *P. obtusum* (Table 3). The ME values of the grasses calculated using the gas method were higher (1.58) than those reported by Juárez *et al* (2007; unpublished data) in introduced grasses from the dry tropics in Mexico (1.33 Mcal/kg DM); however are lower than those reported by Getachew *et al*. (2005), in a study evaluating 17 feed ingredients (1.84 – 3.24 Mcal/kg DM). Nonetheless, the mean values obtained in this study indicated that the energy requirements for maintenance of sheep would not be satisfied (1.8 Mcal/kg DM; NRC, 2007).

The MP content in all grasses was significantly different among seasons and among grasses within seasons (Table 3). The highest MP contents in the studied grasses were observed in summer and fall (mean = 7.3 % DM), probably as a consequence of the important rainfall registered during this period of the year. It is to notice that MP of *P. obtusum* was always higher than 7.0 % DM throughout the year, whereas in other grasses the MP content varied from 5.0-8.5 % DM. The lowest MP contents were recorded during winter and spring (6.0 % DM), whereas during summer and fall the MP content increased up to 7.3 % DM, probably as a consequence of higher CP contents registered in this period. These variations in MP content in grasses throughout the year are in agreement with the fact that grazing pastures undergo important nutrient fluctuations along the seasons which may affect animal performance (Bouquier *et al*. 1988). *Tridens eragostoides, P. obtusum, S. macrostachya* had a higher MP content in winter and spring than *C. ciliaris* used as reference good quality grass. A similar pattern was observed in *P. unispicatum, B. curtipendula, P. obtusum,* and *L. filiformis* in summer and fall. Mean MP values (6.8 g/kg DM) in this study indicate that the consumption of grasses might fulfill the maintenance requirements of a 7.0 % growing beef cattle (Bouquier *et al*. 1988).

Data obtained from range sheep (Juárez *et al*, unpublished data) indicated a mean MP dietary content of 6.8 % DM. In that study, the animals mainly selected a mixture of native grasses. It is important to notice that according to the PDI system (INRA, 1988), CP concentrations above 12% might indicate that the energy content of grasses become the limiting factor; on the contrary, when the CP concentration is below 11%, nitrogen limit the growth of rumen microbiota. In the present study, most grasses reflected the latter scenario. Therefore, the MP content of grasses estimates more accurately the nutritional value of forages than other simply chemical determinations.

Table 2. Seasonal and annual means of the DM *in situ* digestibility parameters and effective degradability of DM in grasses

Grasses	a, % DM							b, % DM						
	Seasons							Seasons						
	w	sp	su	f	M	SEM	Sig	w	sp	su	f	M	SEM	Sig
B. curtipendula	16	19	18	20	18	0.2	***	27	24	26	24	25	0.3	**
B. trifida	16	21	23	21	20	0.2	***	24	21	20	25	22	0.4	**
B. fasciculata	18	19	36	21	23	0.3	***	28	23	32	32	29	0.4	***
C. ciliaris	19	26	32	23	25	0.3	***	29	28	31	36	31	0.5	***
C. ciliata	22	21	32	25	25	0.2	***	23	24	25	19	23	0.2	***
D. insularis	26	23	26	23	24	0.1	***	18	28	29	32	27	0.3	***
L. filiformis	18	19	20	23	20	0.2	***	27	29	34	34	31	0.5	***
P. hallii	18	21	26	24	22	0.2	***	21	24	34	29	27	0.5	***
P. obtusum	20	35	31	26	28	0.1	***	20	20	45	31	29	0.4	***
P. unispicatum	16	21	26	26	22	0.2	***	27	20	24	29	25	0.2	***
R. repens	19	25	25	23	23	0.2	***	25	21	19	23	22	0.2	***
S. grisebachii	18	25	32	23	24	0.2	***	27	19	44	28	29	0.4	***
S. macrostachya	18	21	27	22	22	0.1	***	21	22	40	24	27	0.5	***
T. eragrostoides	24	23	24	19	22	0.1	***	23	23	32	25	26	0.6	**
T. muticus	16	21	25	21	21	0.1	***	24	20	36	22	26	0.3	***
Seasonal means	19	23	27	23	23			24	23	31	27	26		
SEM	0.3	0.3	0.4	0.1				0.3	0.3	0.4	0.1			
Significant level	*	**	***	**				***	**	***	**			

Table 2 Continued.-

	c, % DM							EDDM, % DM						
B. curtipendula	5	4	6	6	5	0.2	***	35	38	36	38	37	0.2	***
B. trifida	5	5	6	6	6	0.2	*	33	37	38	39	37	0.1	***
B. fasciculata	5	6	4	6	5	0.1	***	38	36	58	45	44	0.3	***
C. ciliaris	6	7	3	6	6	0.2	***	39	47	53	50	47	0.2	***
C. ciliata	6	7	4	7	6	0.1	***	39	40	50	40	42	0.1	***
D. insularis	4	6	7	5	6	0.1	***	38	44	48	46	44	0.2	***
L. filiformis	5	4	4	6	5	0.1	***	38	40	44	49	43	0.4	***
P. hallii	6	5	4	6	5	0.2	**	36	39	49	45	43	0.3	***
P. obtusum	5	7	2	5	5	0.2	***	35	41	59	49	46	0.2	***
P. unispicatum	5	6	5	6	6	0.1	**	35	36	43	47	40	0.1	***
R. repens	5	6	6	5	6	0.1	***	38	41	41	39	40	0.1	***
S. grisebachii	6	6	3	6	5	0.1	***	38	39	62	43	42	0.2	***
S. macrostachya	5	6	3	5	5	0.1	***	33	37	54	40	41	0.3	***
T. eragrostoides	5	5	3	5	4	0.1	***	41	41	44	38	41	0.2	***
T. muticus	5	6	4	5	5	0.1	***	34	36	51	37	39	0.2	***
Seasonal means	5	6	4	5	5			37	40	49	43	42		
SEM	0.7	0.1	0.1	0.1				0.2	0.3	0.5	0.3			
Significant level	*	***	***	**				***	***	***	***			

w= winter; sp= spring; su= summer; f= fall; SEM = standard error of the mean; Sig= significancy; *(P<0.05); **(P<0.01); ***(P<0.001).
a = intercept representing the portion of DM solubilized at the beginning of incubation (time 0).
b = portion of DM that is slowly degraded in the rumen.
c = rate constant of disappearance of fraction b.
EDDM = Effective degradability of DM assuming an out flow rate of 2% h^{-1}

Conclusions

Even though CP of grasses content was affected by climatic conditions, all grasses, in all seasons, had sufficient CP and MP content to meet the maintenance requirements (7.0%) of growing beef cattle; higher levels were observed in summer and autumn. The same pattern occurred in EDDM. Because of their higher CP and MP and mineral content, grasses such *as B fasciculata*, *C. ciliata*, *P. hallii*, *P*, *obtusum*, *S.*, *grisebachii*, *S. macrostachya* and *T. eragrosto*ides can be considered of good nutritional quality. In this study, *Rhynchelytrum repens* had lower nutritional quality than C. ciliaris.

Table 3. Seasonal and annual means of the metabolizable energy (ME) content (Mcal kg^{-1} DM) calculated from *in vitro* gas production and metabolizable protein (MP) content (g kg^{-1} DM) for grasses

Grasses	ME, Mcal kg^{-1} DM				M	SEM	Sig	MP, % DM				M	SEM	Sig
	Seasons							Seasons						
	w	sp	su	f				w	sp	su	f			
B. curtipendula	1.49	1.46	1.60	1.57	1.53	0.01	***	5.9	5.7	5.7	8.0	6.3	4	***
B. trifida	1.51	1.21	1.46	1.45	1.42	0.05	**	5.0	5.0	5.3	7.7	5.5	1	***
B. fasciculate	1.63		1.64	1.32	1.53	0.02	***	6.3		7.5	72	7.2	1	***
C. ciliaris	1.80	1.50	1.81	1.75	1.71	0.03	***	5.6	5.9	8.8	7.8	7.0	2	***
C. ciliata	1.55	1.65	1.54		1.58	0.15	NS	7.0	6.3	7.7		7.0	2	***
D. insularis	1.63		1.57	1.69	1.63	0.03	**	7.1		6.5	7.4	7.0	2	**
L. filiformis	1.86		1.59	1.88	1.78	0.02	***	7.1		7.4	7.8	7.4	2	*
P. hallii	1.56	1.37	1.62	1.50	1.51	0.03	***	6.4	4.7	8.6	7.5	6.6	5	***
P. obtusum	1.72	1.72	1.67	1.79	1.72	0.05	NS	7.3	7.6	7.2	8.2	7.6	2	**
P. unispicatum	1.59	1.40	1.81	1.63	1.61	0.13	***	5.0	5.3	8.2	7.9	6.6	4	***
R. repens	1.70	1.64	1.51	1.41	1.60	0.03	***	5.2	4.5	6.8	6.3	5.9	1	***
S. grisebachii	1.70	1.47	1.69		1.62	0.05	**	5.7	6.0	7.1		6.3	4	**
S. macrostachya	1.55	1.45	1.61	1.17	1.45	0.04	***	7.0	6.7	7.0	5.3	6.5	3	***
T. eragrostoides	1.61	1.69	1.84	1.48	1.66	0.02	***	7.2	5.4	7.8	6.9	7.4	2	**
T. muticus	1.48	1.31	1.66		1.48	0.02	***	5.3	5.2	7.4		5.9	2	***
Seasonal means	1.62	1.49	1.64	1.55	1.57			6.3	5.9	7.3	7.3	6.7		
SEM	0.02	0.03	0.10	0.03				3	2	3	2			
Significant level	***	***	**	***				***	***	***	***			

ME (Mcal kg^{-1} DM) calculated as: (2.20 + 0.136 Gas $Prod_{24h}$ + 0.057 Crude Protein + 0.0029 Crude Fat^2)/4.184.
MP calculated as: PDIA = 1.11 * PC (1 - Degradabily) * degradability in small intestine; PDIMN = 0.64 * PC * (degradability at 48h -0.10); PDIME = 0.093 * Organic matter fermented in the rumen
w= winter; sp= spring; su= summer; f= fall; SEM = standard error of the mean; Sig= significancy; *(P<0.05); **(P<0.01); ***(P<0.001); NS not significant.

However, the ME content of the forages calculated from *in vitro* gas production may not meet the maintenance requirements of sheep. Although the MP content confirms the good quality of studied grasses, it was also observed, in most grasses, that CP content might be the limiting factor for the growth of rumen microbiota and productive purposes.

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