ELSEVIER Animal Feed Science and Technology 80 (1999) 101–113

ANIMAL FEED SCIENCE AND TECHNOLOGY

Feed value of native forages of the Tibetan Plateau of China

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Received 25 August 1998; received in revised form 2 March 1999; accepted 29 March 1999

Abstract

The nutritive value of 22 native forages consisting of sedge, grass, forb and shrub species harvested in August, September and October from the Tibetan Plateau of China was assessed by using chemical, in sacco degradability and in vitro gas production analyses. Generally, data from the study showed that metabolizable energy value (ME) as estimated by in vitro gas production and chemical composition data decreased with maturity. Forb forages had the highest ME value (9.18 MJ/kg) and grasses the lowest (8.74 MJ/kg). ME value of grasses showed a sharp decrease from August to September, then it remained constant. Other forages showed a linear decrease of ME value with maturity. The relative decrease in the content of nitrogen available for microbial degradation (degradable N g/kg DOM) with maturity was similar for sedge, grass and forb species. Grazing of sedges and forbs in mixed communities of grasses may be important for supplying extra nitrogen for microbial fermentation and increasing efficiency of utilisation of grasses. Data from in vitro gas production completed in presence of polyethylene-glycol 4000 (PEG), a phenolic-related binding agent, showed that some species of sedges, forbs and shrub might contain large amounts of inhibitory compounds to rumen microbes. Further in vivo studies are needed to establish optimum levels of inclusion of such plants in Yak diets to optimise grassland use and animal performance. Finally, data from grasses suggested that such forages should preferably be grazed by August while their nutritive value was high. © 1999 Elsevier Science B.V. All rights reserved.

Keywords: Tibetan forages; Nutritive value; Grassland management; In sacco degradability; In vitro gas production

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PII: S0377-8401(99)00057-7

1. Introduction

Tibetan Plateau is one of the three most important livestock production areas in China. With an area of 129.3×10^6 ha of grassland, it accounts for 32.5% of China total grassland area (Long and Ma, 1996). There are ca. 41.5×10^6 sheep (*Ovies aries*) and 13×10^6 yaks (*Bos gruniens*) in the Plateau. Such herds are largely dependent on the native grassland to survive. Therefore, livestock production in that area is strongly influenced by climatic conditions. For instance, when heavy snowfall occurs during spring season, losses of up to 30% of the Yak population has been reported (Long and Ma, 1996). The animal husbandry system in Tibetan Plateau faces higher risk as compared with other regions in China, where animals can find alternative grassland for the winter months (Long, 1995). Grazing management in the Plateau is carried out by seasonal rotation system, whereby the animals are moved to a different area with the approach of a new season. Alpine and sub-alpine herbage meadows consisted of sedge, sedge-grass, sedge-forb, forb and shrub meadows constitute the main part of the grassland in this cold and semi-humid Plateau. Other two types of alpine steppe and alpine desert can also be found. The alpine and sub-alpine meadows are grazed as winter and spring pastures in most areas for at least eight months. The main species found in the sedge meadow are *Carex atrofusca*, *Kobresia humilis*, *Kobresia capillifolia* and *Kobresia pygmaea*. Grasses such as *Elymus nutans*, *Roegnevia kamoji*, *Stipa aliene* and *Koeleria litwinowii* are common species in the sedge-grasses meadow. Some forb species, e.g. *Polygonum viviparum*, *Polygonum alatum* and *Potentilla repans* can easily build their own dominant communities, whereas other species often grow in association with sedges and grasses. In over grazed areas, forbs and some seasonal toxic plants such as *Oxytropis ochrocephala* and *Ranunculus pulchollus* dominate both sedge and grass species. Shrub forages, e.g. *Dasiphora fruticosa* and *Salix* sp., form important communities of summer pastures that can be grazed for up to 75 days.

Since vegetation is the foundation for Tibetan Plateau grassland farming, development of appropriate strategies for sustainable development of the grassland resources requires information on the type, quality and availability of forages throughout the year. There is limited information on nutritive value of native plants available to Yaks in China. Similarly, very little is known about changes in their characteristics as affected by season. The aim of the current study is to estimate the nutritive value of the native forages harvested from the Tibetan Plateau in August, September and October. The results should help us better understanding the feed potential of such forages and improving grassland management strategies in the region.

2. Materials and methods

2.1. Feed samples

Samples from 22 native plant species were collected on 5 August, 20 September and 20 October 1996 from Yingfengtan Alpine Meadow of the northeast of Tibetan Plateau located in the Tianzhu Tibetan Autonomous County, Gansu, China. Samples consisted of four sedges—tufted marsh grass-like plants, which belongs to the *Cyperaceae* family, differing from the related grasses in having achenes and solid stems: *Carex atrofusca*, *Kobresia humilis*, *Kobresia capillifolia*, and *Kobresia pygmaea*; seven grasses: *Elymus nutans*, *Roegnevia kamoji*, *Stipa aliene*, *Deschampsia caespitosa, Koeleria cristata*, *Koeleria litwinowii* and *Leymus secalinum*; 10 forbs—broad-leaved herbs: *Polygnum viviparum*, *Polygnum alatum*, *Potentilla repans*, *Oxytropis ochrocephala*, *Carum carvi*, *Allium sikkimense*, *Ajania frigida*, *Anaphalis lactea*, *Trigonella ruthehica* and *Ranunculus pulchollus*; and one shrub species: *Dasiphora fruticosa*. Samples were oven dried at 50°C for 48 h and milled through a 1.0 mm screen for in vitro studies and chemical analysis or through a 2.5 mm screen for in sacco degradability studies.

2.2. Chemical analysis

Dry matter and ash contents were determined as described by AOAC (1984). Neutral detergent fibre (NDF) was determined according to the method described by Van Soest et al. (1991). Total nitrogen analysis was carried out by an automated method (Davidson et al., 1970).

2.3. In vitro gas production

Rumen fluid was collected from three wether sheep fitted with rumen cannulae, which were fed twice daily on a diet consisted of 67% ryegrass hay (N 2.05%, DM basis) and 33% artificial dried grass (N 2.56%, DM basis). Rumen fluid was strained through gauze and mixed with the buffer solution in a 2 : 1 ratio (Menke and Steingass, 1988). About 200 g dried forage sample was incubated at 39°C with 30 ml rumen liquor–buffer mixture in 100 ml glass syringes and readings taken after 0, 3, 6, 12, 24, 48, 72 and 96 h incubation. All gas production data were corrected for 200 mg dry matter basis and fitted into an exponential equation: $P = 1 + b(1\text{-e}^{-ct})$ (Ørskov and McDonald, 1979).

The metabolizable energy (ME) and degradable organic matter (DOM) data were estimated from the gas production and chemical composition results (Menke and Steingass, 1988). Degradable nitrogen (dN) was estimated by in sacco technique after 48 h incubation. Data were then expressed as the dN/DOM (g/Kg DM) ratio.

2.4. Assessment for inhibitory compounds

Samples were also incubated in vitro as described before with polyethylene glycol 4000 (PEG) on a 1 : 1 sample/PEG ratio to evaluate the effect of phenolic-related inhibitory compounds on in vitro gas production (Makkar et al., 1995).

2.5. In sacco dry matter degradability analysis

Analysis was carried out according to the procedure described by Mehrez and Ørskov (1977). About 2.5 g sample was transferred into nylon bag and incubated in three rumen fistulated sheep (one bag per sheep) for 48 h. Animals were fed as described above. On removal, nylon bags were thoroughly washed and dried at 60°C for 48 h. Washing losses were measured by soaking nylon bags containing samples at 39°C for 1 h prior to washing.

2.6. Statistical analysis

Data were subjected to analysis of variance (ANOVA) using general linear model.

3. Results

3.1. Climatic conditions

The alpine meadow, where samples were collected, is located on the parallel 37°40′ N and 180°32′ E at an altitude ranging from 2900 to 3300 m. Annual mean temperature is −0.1°C. July is the warmest month with a mean temperature of 12.7°C. Frost may occur at any time of the year. The average annual rainfall is 416 mm. Snow rarely occurs in winter months, although it is common between February and May. Annual solar radiation ranges from 5700 to 6000 MJ/m^2. Native plants only grow for 120–140 days of the year and the biomass production is easily affected by drought.

3.2. Observed patterns of forage production

The growth of native herbage, in particular sedges and grasses, in the Tibetan Plateau starts in mid-May and finishes in mid-September (Fig. 1), when the weather is warm and wet. The first (July) and second (September) peaks of biomass production were the result of fast growth of both sedges and grasses, respectively. Three distinct phases of biomass

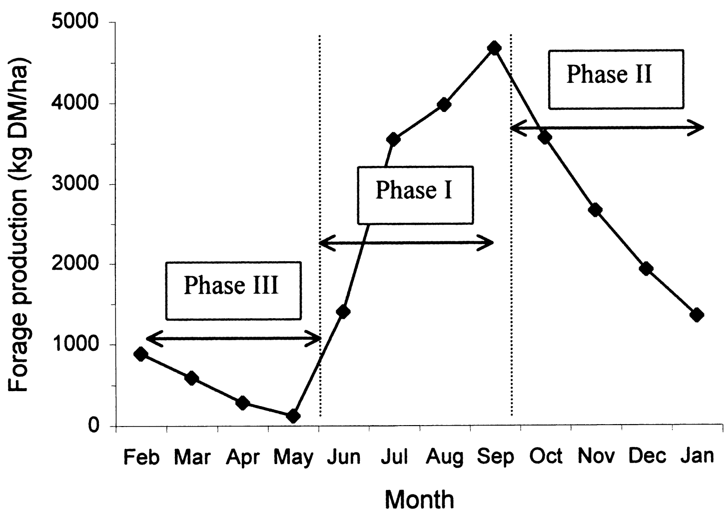

Fig. 1. Biomass production of alpine meadows in the Tibetan Plateau.

availability to the animals could be identified. Phase I: surplus of green forages (June–September); Phase II: a relative surplus of more mature and dry forages (October–January), and Phase III: shortage of dry forages (February–May). Despite the lack of food observed in Phase III mortality rate of animals in the Tibetan Plateau is only 3–5% per year. However, in the event of heavy snowstorms during spring mortality can reach 20% (Long and Ma, 1996).

Sedges (*C. atrofusca*, *K. humilis* and *K. capillifolia*) and grasses (*E. nutans*, *R. kamoji*, *S. aliene* and *K. litwinowii)* are main species found in the sedge and sedges-grass meadows. Such meadows are grazed during the winter and spring seasons as standing dry biomass. The forb species of *P. viviparum*, *P. alatum* and *P. repans* are the most important forages in the forb meadows, which is found in wet areas (Hu et al., 1994). Shrubs such as *D. fruticosa* and *Salix* sp. are widespread in summer pastures, which is grazed for 45–75 days. In general, all native forages described in this study are 10–25 cm high, therefore, unsuitable for haymaking.

3.3. Forage chemical composition

Chemical composition of the Tibetan forages collected are shown in Table 1. In general, increasing age at harvesting lead to significant decrease in nitrogen content of all forages ($p < 0.01$) and increase in NDF content of both forbs and shrubs ($p < 0.05$). Nitrogen content in sedges and forbs tended to be greater than that of grasses. With the exception of a shrub, four species of forbs (*O. ochrocephala*, *C. carvi*, *A. lactea*, and *T. ruthehica*) and one species of sedge (*C. atrofusca*) the nitrogen content of all other forages harvested in October was fairly low, i.e. between 0.42% and 0.98%. The relative increase in NDF content with ageing was highest in shrub (11.4% to 54.3%), followed by forbs (15.6% to 36.4%), sedges (3.4% to 8.1%) and grasses (1.5% to 2.7%).

3.4. Forage nutritive value as estimated by in vitro and in sacco methods

The 24 h in vitro gas production and 48 h in sacco degradability data are presented in Table 2. In vitro gas production of forages harvested in August tended to be higher than that of September and October samples. However, *K. capillifolia*, *D. caespitosa* and *K. litwinowii* showed an opposite trend in the October cut. Similarly, 48 h in sacco dry matter degradability decreased with increasing maturity. *D. caespitosa* grass was the only species that showed higher gas production and degradability data in the October cut. Comparison amongst forages harvested in all three periods indicated that forbs had the highest 48 h in sacco dry matter degradability, followed by sedge, grass and shrub.

In vitro gas production data of the most important sedge, grass and forb species are illustrated in Figs. 2–4, respectively. Data clearly indicated the negative effect of maturity on the nutritive value of such forages.

Correlation between 48 h in sacco degradability and in vitro gas production after 12, 24 and 48 h as well as potential gas production are shown in Table 3. The 48 h degradability data of all samples was positively correlated with the 24 h gas production ($r = 0.73$, $p < 0.001$). The highest correlation was observed in grasses ($r = 0.92$) followed by sedges

Table 1
Nitrogen and neutral detergent fibre (NDF) content of some Tibetan forages at different stages of maturity (on dry matter basis)

Forage	Harvesting time month					
Group, *species*	August	September	October	August	September	October
	Nitrogen (%)			NDF		
Sedge						
C. atrofusca	2.02	2.03	1.25	63.6	69.2	69.7
K. humilis	2.01	1.37	0.74	66.7	67.7	69.5
K. capillifolia	2.20	1.45	0.53	68.1	64.0	72.9
K. pygmaea	1.47	0.69	0.50	63.2	69.4	71.0
Mean	1.93	1.41	0.80	65.4	67.6	70.7
SED [a]	0.01	0.01	0.02	0.40	0.22	0.94
Grass						
E. nutans	1.91	1.17	0.61	75.7	75.4	83.5
R. kamoji	1.49	0.80	0.46	73.1	77.3	82.4
S. aliene	2.21	1.67	0.89	71.6	73.0	74.4
D. caespitosa	1.49	1.01	0.60	77.2	73.1	75.9
K. cristata	1.14	0.62	0.42	76.2	80.3	71.7
K. litwinowii	1.46	0.60	0.74	74.5	79.6	72.6
L. secalinum	1.80	1.54	0.83	65.1	61.9	74.3
Mean	1.64	1.06	0.65	73.3	74.4	76.4
SED [a]	0.01	0.03	0.01	0.73	0.42	0.66
Forb						
P. viviparum	1.74	1.07	0.93	49.6	51.2	52.1
P. alatum	2.12	1.84	0.98	41.3	38.8	58.7
P. repans	2.45	1.70	0.78	39.3	39.7	38.4
T. ruthehica	3.55	2.66	2.22	29.3	37.8	44.6
C. carvi	2.43	1.48	1.31	46.4	63.6	67.8
A. sikkimense	1.83	1.50	0.74	32.1	42.3	55.3
A. frigida	2.22	1.17	0.87	33.4	38.7	49.4
A. lactea	2.10	1.51	1.08	41.3	32.5	41.7
O. ochrocephala	3.03	2.87	1.66	41.6	47.1	57.7
R. pulchollus	1.94	1.20	0.92	40.3	45.7	52.3
Mean	2.39	1.76	1.17	37.9	43.8	51.7
SED [a]	0.02	0.07	0.01	0.31	0.63	0.86
Shrub						
D. fruticosa	1.97	1.52	1.09	48.4	53.9	74.7

[a] Standard error of the difference.

($r = 0.84$) and forbs ($r = 0.66$). Correlation coefficient of the latter was not improved ($p > 0.01$) when gas production data from PEG added forb samples were correlated with in sacco data.

As the estimation of nutritive value can be affected by sample chemical composition, for instance a protein forage will have its gas production and energy value underestimated by the gas production method, energy value was also estimated as metabolizable energy

Table 2
In sacco dry matter degradability (ISD) and in vitro gas production (GP) data of some Tibetan forages at different stages of maturity

Forage	Harvesting month					
Group, *species*	August	September	October	August	September	October
	48 h ISD (%)			24 h GP (ml)		
Sedge						
C. atrofusca	77.8	72.6	59.3	34.5	33.3	25.0
K. humilis	75.0	63.5	65.6	31.7	26.6	24.7
K. capillifolia	80.3	76.0	77.7	36.5	33.8	44.3
K. pygmaea	74.9	70.5	67.5	35.1	32.5	31.3
Mean	77.0	70.7	67.5	34.4	31.6	31.3
SED [a]	2.58	3.20	3.11	1.29	1.11	1.91
Grass						
E. nutans	69.7	63.1	51.8	38.4	29.6	23.7
R. kamoji	65.0	55.0	51.0	37.5	25.3	27.0
S. aliene	75.6	62.2	63.3	38.1	35.1	33.3
D. caespitosa	62.1	61.9	70.1	31.7	30.7	39.6
K. cristata	63.5	48.4	52.6	32.1	24.2	23.8
K. litwinowii	66.3	47.6	64.5	39.4	22.5	34.6
L. secalinum	76.6	77.1	60.6	39.6	39.0	28.6
Mean	68.4	59.3	59.1	36.7	29.5	30.1
SED [a]	1.24	2.10	1.65	0.64	0.93	0.75
Forb						
P. viviparum	65.5	60.2	60.9	28.4	19.9	21.3
P. alatum	75.0	74.1	53.7	29.1	26.7	20.6
P. repans	77.4	69.5	78.1	23.5	21.0	22.3
T. ruthehica	90.1	85.0	79.9	44.5	32.3	30.2
C. carvi	78.5	58.3	53.6	39.6	28.2	25.6
A. sikkimense	82.6	74.8	66.8	45.4	42.0	34.6
A. frigida	81.7	74.0	65.5	38.9	37.8	31.3
A. lactea	85.3	89.5	87.1	32.6	39.1	27.5
O. ochrocephala	85.4	78.5	71.2	39.8	34.8	32.4
R. pulchollus	81.1	78.5	74.5	44.8	39.5	36.7
Mean	80.3	74.2	69.1	36.6	32.1	28.2
SED [a]	2.50	1.12	1.54	2.07	1.40	1.76
Shrub						
D. fruticosa	51.7	44.6	32.2	32.2	16.1	10.8

[a] Standard error of the difference.

(Menke and Steingass, 1988). This approach takes into account both gas production and chemical composition for predicting energy value. Mebolizable energy (ME) value of the Tibetan forages ranged from 8 to 11 MJ/kg DM, except for shrubs, which was significantly lower (5.45–6.91) (Fig. 5). The estimated ME value of ryegrass hay (control feed) was 9.45.

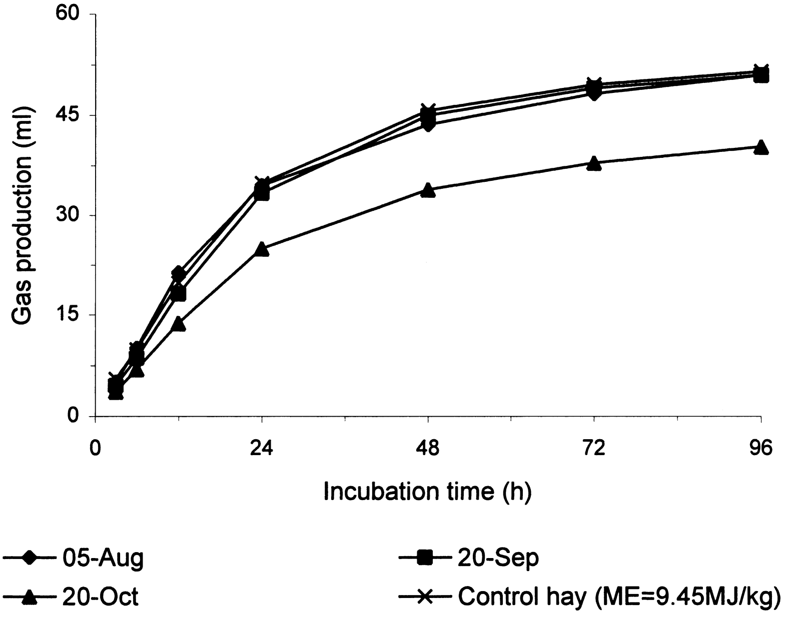

Fig. 2. Effect of maturity on in vitro gas production of *Carex atrofusca* sedge.

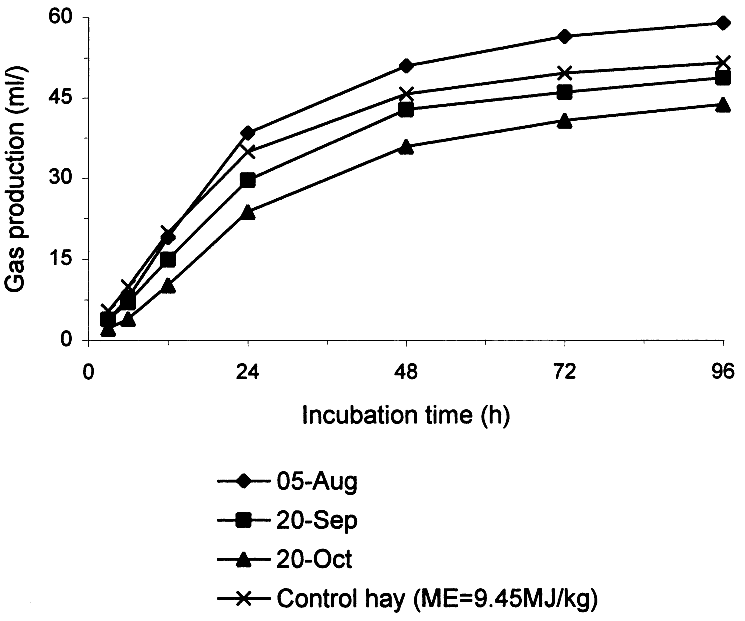

Fig. 3. Effect of maturity on in vitro gas production of *Elymus nutans* grass.

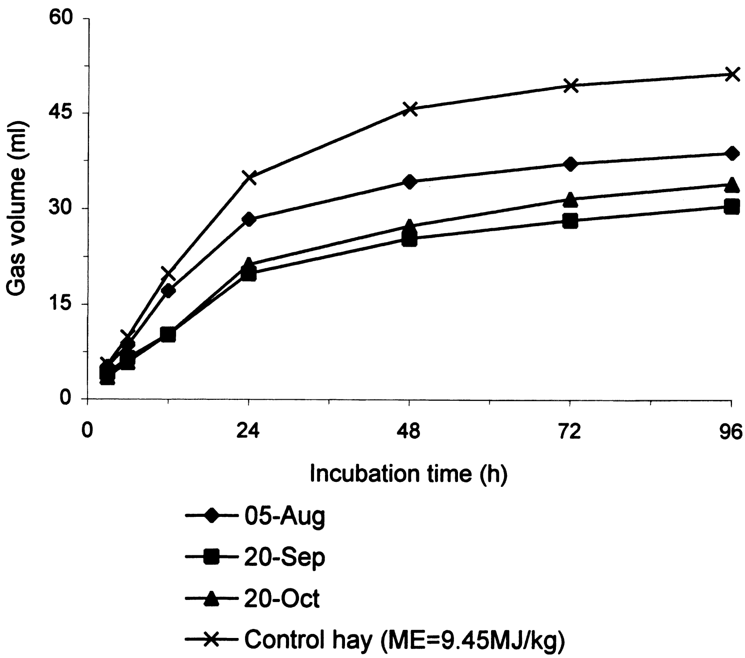

Fig. 4. Effect of maturity on in vitro gas production *Polygonum alatum* forb.

The degradable N/DOM value varied from 6.7 (October grasses) to 36.7 g/kg (August forbs). Data also indicated that relative decrease in degradable N/DOM was greater than that of metabolizable energy.

3.5. Presence of microbial inhibitory compounds

Table 4 illustrates the positive effect of adding PEG to six different forage species. The highest increase in gas production after 12 and 24 h incubation, respectively, was observed in *P. alatum* (72.2% and 37.3%) and *P. viviparum* (58.9% and 39.1%) Fig. 6.

Table 3
Correlation (r coefficient[a]) between 48 h in sacco dry matter degradability and in vitro gas production data of some Tibetan forages

		In vitro gas production (h)			
Forage group	n	12	24	48	$a+b$ [b]
Sedge	11	0.900	0.842	0.777	0.822
Grass	27	0.903	0.924	0.928	0.870
Forb	30	0.611	0.659	0.659	0.665

[a] $p < 0.01$.
[b] Potential gas production.

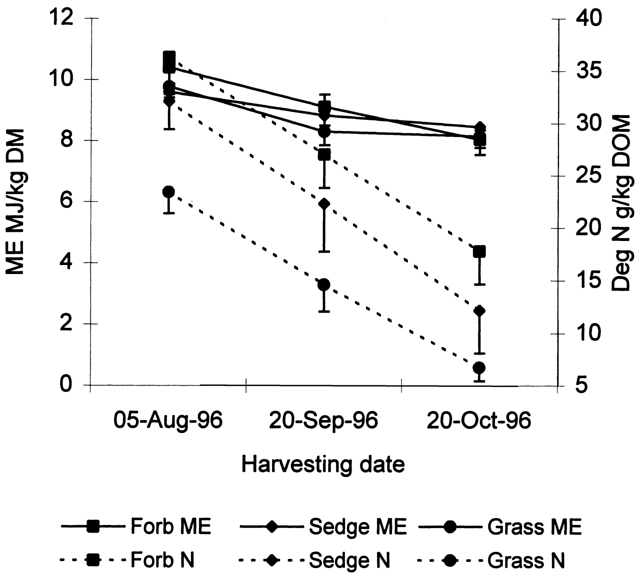

Fig. 5. Effect of maturity on the nutritive value of forb, sedge and grass species from the Tibetan Plateau (error bar in figure represents standard error).

Table 4
Effect of phenolic-binding agent polyethylene glycol 4000 (PEG) on gas production in vitro from some Tibetan forages

Forage species	Harvesting month	12 h incubation		24 h incubation	
		GP (ml) [a]	% increase [b]	GP (ml)	% increase
K. humilis	August	17.2	9.50	34.4	4.80
	September	15.6	14.0	29.0	15.1
	October	10.6	15.4	27.1	14.0
K. pygmaea	August	17.8	12.3	35.6	9.20
	September	12.3	13.3	34.4	7.90
P. viviparum	August	17.5	52.8	29.3	27.6
	September	10.7	73.0	19.2	52.2
	October	10.4	50.9	20.5	37.6
P. alatum	August	13.5	83.1	28.7	39.2
	September	13.2	80.3	25.7	43.2
	October	7.30	53.2	18.9	29.6
P. repans	August	14.6	30.0	26.6	18.6
	September	14.3	24.8	24.4	21.3
	October	13.1	44.4	22.7	32.9
D. fruticosa	August	9.60	28.6	14.8	70.4
	September	9.60	34.3	15.9	44.8
SED [c]		0.36		0.44	

[a] Gas production from samples incubated in absence of PEG.
[b] Percentage increase on gas production from samples incubated in presence of PEG.
[c] Standard error of the difference.

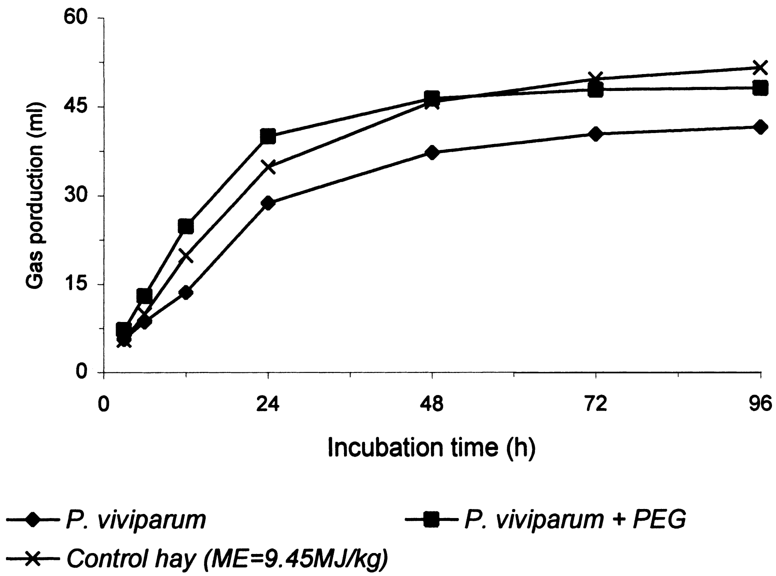

Fig. 6. Gas production of *Polygonum viviparum* incubated with or without polyethylene glycol 4000.

There was no clear trend on the effect of maturity upon the response to PEG in vitro. Gas production from grass samples did not respond to addition of PEG in vitro ($p > 0.01$).

4. Discussion

As ruminant species, there are no significant differences in forage utilisation amongst yak, sheep and goat (Cincotta et al., 1991). Generally, shift in quantity and quality of Tibetan forages as described in this study affect performance of Yaks. Long (1995) reported that crude protein content of mixed forages collected from sedge-grass meadow in December and April was 6.92% and 6.96%, respectively. A 30% decrease in dry matter intake and body weight was observed in Yaks during spring compared to that of summer and autumn.

Sedge forages are the dominant indigenous species in the Tibetan Plateau due to their high biomass production, early re-growth, wide distribution and good resistance to both over grazing and extreme climatic conditions. The sedge and sedge-grass meadows are of particular importance in the spring season, which is a critical period for animal survival. Additionally, most parturition among Yaks and Tibetan sheep occurs within this period. Cincotta et al. (1991) also indicated that sedge species accounted for 64.1% and 38.4% in yak and sheep diets, respectively, during summer time.

D. fruticosa communities are often mixed with grass, sedge and forb species located in high mountains and usually grazed in the summer only. In this part of the year Yaks would tend to escape from the hot climate in the low lands. Data presented here indicates a high energy and in particular protein level of *D. fruticosa*. In such mixed communities, this species can be very useful in providing extra dietary nitrogen so that other forages can be more efficiently utilised as energy sources.

Another important observation was that grasses, sedges and forbs had a similar relative decrease in degradable N/DOM with maturity (Fig. 5). Additionally, relative decrease in energy value (ME) with forage maturity was lower than that of degradable gN/DOM. This implies that N may become a limiting factor to animal nutrition before that of energy. It is also important to note that loss of nutritive value in grasses occurs rapidly after its growth, therefore intensive grazing in the summer months in grass meadows may be advisable. Additionally, grazing of N rich forages in combination with grasses, particularly in the summer months, should help meeting the requirement for rumen degradable protein and improve animal performance.

Long (1995) reported that urea concentration in serum was highest (8.0 mmol/l) in Yak during August and reduced thereafter to a minimum value of 4.4 in February. This reflects the poor protein status of Yaks from October onwards. Protein content and degradable N/DOM data from this study clearly indicates that supply of N becomes critical in that period.

Long (1995) also reported that glucose status as measured by ß-OH butyrate (BHB) concentration in the serum of Yaks was relatively constant from August to October (0.70–0.75 mmol/l). The small decrease in energy value of the forages analysed in the current study agrees with such report.

Forb meadow should be utilised during autumn and early winter to avoid loss of leaves, hence decrease in nutritive value, generally caused by snowfall and strong winds in spring. Data from this study suggest that there might be phenolic related anti-nutritive factors in such forages, which might affect both intake and digestion of swards containing high proportion of *P. viviparum*, *P. alatum* and *P. repans* forbs.

It was also observed a relative decrease in the response to PEG with increasing incubation time in vitro, which may be explained by an adaptation mechanism of the rumen microbes to phenolic-related compounds (Menke et al., 1992). Additionally, rumen liquor used in this study was collected from sheep fed on grass hay diet, therefore, leading to a microbial population that may not be adapted to metabolise such compounds. Therefore, an over estimation of the toxicity in vitro of such phenolic-related compounds may have occurred. Further work is needed to identify the inhibitory effect of such compounds when Yaks are fed on specific forb species.

Acknowledgements

The technical assistance rendered by Mr. W.J Shand and D. Kyle is highly appreciated. We are also grateful to Mr. S.K. Dong, Y.W. Yu and X.P. Pu who assisted in sample collection on Tibetan Plateau, China.

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