In vivo degradation kinetics of Tibetan forage

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Abstract

The objective of the current study was to evaluate chemical composition and degradability characteristics for eight forages harvested in July from the Tibetan plateau of China. Duplicate bags containing 2 g of forage species were incubated in the rumen of six ruminally cannulated Tibet Peng-Po sheep for 0, 3, 6, 12, 24, 48 and 72 h. Significant differences were observed in degradation kinetics and effective degradability values of the different forages. The rapid degradable value and potential degradability for dry matter (DM) and neutral detergent fibre (NDF) in Lagotis humilis was higher (P<0.01) than for the other forages. Carex satakeana had the most rapidly degradable crude protein (CP) fraction of all forages tested and Elymus nutans had the highest potential degradability of CP. L.humilis, C.satakeana and E.nutans had high effective degradability of DM and CP indicated their high quality as ruminal forage in cold areas of Tibet.

Introduction

Tibet is one of the five major pastoral areas in China. With an area of 35x10^6 ha of utilizable grassland, it accounts for 67% of Tibetan total grassland area. Approximately 1.03x10^6 sheep, 6.46x10^6 goats and 4.85x10^6 yaks are grazed on the plateau. This level of grassland husbandry is largely dependent on the survival of the native grasslands. Grasses and sedges are the primary forages fed on by livestock in the alpine and sub-alpine meadows. These forages build their own firm communities with other species and are grazed as winter and spring pastures in most areas for at least eight months (Long et al. 1999). Therefore, the sedge and sedge-grass meadows are of particular importance in the spring season, which is a particularly critical period for livestock survival. Accurate prediction of forage quality allows producers managing rangelands to meet specific animal requirements (Valente et al., 2000). Some of the parameters needed to determine the nutritive value of forage are based on chemical composition and digestibility, measured either in vitro or in vivo (Minson, 1990). The in vivo technique has become more and more popular as a method to quantify the rumen degradable fraction and is now widely used throughout the world (Wilkerson et al., 1995). This technique allows a number of feedstuffs to be evaluated at the same time and is accepted as a basic analytical technique by most organizations (von Keyserlingk et al., 1996).

The Peng-Po variety of semi-wool sheep was first bred in Tibet for higher production of wool and mutton. It is now becoming a representative breed in Tibet, which has resulted in changes in local animal husbandry. There is not yet any information available regarding the nutritive value of native forages used for Peng-Po sheep feeding on the Tibetan plateau.

Therefore, the objective of the current study was to characterize the nutritive value, ruminal degradation characteristics and effective degradability of DM, CP and NDF for some forage species common to an alpine meadow in Tibet.

Materials and methods

Samples

Samples were collected on 2 July 2008 from a Kobresia humilis meadow in Naqu County (latitude 31°28′N, longitude 92°03′E) at an altitude of 4527 m a.s.l., north of the Tibetan Autonomous Region, China. Annual mean temperature is 2.1°C. Frost may occur at any time of the year. Annual sunshine hours range from 2852.6 to 2881.7. The average annual rainfall is 420 mm. July is the warmest month with a mean temperature of 9°C. Native plants grow for only 120-140 days of the year and plant biomass is readily affected by drought. The best grazing season is during the rainy season (June to September). Samples consisted of three sedges: Carex satakeana, Kobresia myosurus and Kobresia humilis (Cyperaceae); three grasses: Stipa aliena, Poa annua and Elymus nutans (Poaceae); Lagotis humilis (Scrophulariaceae); and Potentilla ansaria (Rosaceae). Each sample (2 kg) was cut by scissors at a 2 cm stubble. S.aliena and E.nutans were harvested at heading, the rest were at the anthesis stage. Samples were oven dried at 55°C for 48 h and then ground to pass a 1 mm screen for chemical analysis, and a 2 mm screen for the in vitro degradability study (Turgut and Yanar, 2004).

Animals and diets

Six Peng-Po sheep wethers, aged 15 months, weighing 35±3 kg and fitted with a rubber rumen cannula, were used to determine the degradability of forage using the nylon bag technique. The wethers were fed for 14 days prior to the ruminal incubation to allow the sheep getting used to their diets. The diets consisted of 67% hay and 33% concentrate on a DM basis. The concentrate was a mixture of corn (72.7%), wheat bran (20.8%), soybean meal (3%), premix (1.1%), salt (1.8%) and limestone (0.6%). The chemical composition of the diet was, on a DM basis, 12.45% CP, 36.88% NDF, 24.89% acid detergent fibre (ADF), 3% Ca, 1.5% P, and 7.82 KJ/kg metabolic energy (ME). The sheep were fed twice daily (at 08:00 and 17:00 h). The dry matter intake of the animals was 1.1 to 1.2 kg/d. Water was available at all times.
**In situ incubations**

For the experimental digestion analysis, nylon bags (8×16 cm; pore size 45 μm) were filled with 2 g of a dry forage sample. Each forage sample was incubated in duplicate in each sheep for each of the testing time periods: 3, 6, 12, 24, 48 and 72 h. Nylon bags were sealed using rubber bands, and soaked in water at 39°C for 20 min prior to ruminal incubation (Maiga et al., 1996). After extraction from the rumen, the nylon bags were washed in cold running water until the washing ran clear and colourless. Washing loss was determined by similarly washing duplicate bags containing samples that were not incubated in the rumen. The bags were oven dried in an air-forced oven for 48 h at 55°C, weighed and used for analysis of nutrients (Turgut and Yanar, 2004).

**Digestion kinetics**

The DM, CP and NDF degradation data were fitted to an exponential equation \( p=a+b (1−e^{−ct}) \) (Ørskov and McDonald, 1979) where \( p \) is the disappearance of DM, CP and NDF (g.g\(^{-1}\)) at time \( t \). The lag time was estimated according to McDonald (1981) by fitting the model \( p=A \) for \( t\leq t_0 \), \( p=a+b (1−e^{−ct}) \) for \( t>t_0 \). The degradation characteristics of the feeds were defined as \( A = \) washing loss; \( B = (a+b)−A \), representing the insoluble but fermentable material \( (a = \) rapidly degradable fraction, \( b = \) slowly degradable fraction); \( c = \) rate of degradation of B per hour and the lag phase \( (L) = (1/c) \log \left( \frac{b}{[a+(a+b)−A]} \right) \). Potential degradability (PD) (g.g\(^{-1}\)) was calculated as \( (A+B) \), while the effective degradability (ED) was calculated using the formula ED \( (g.g^{-1}) = A + \frac{Bc(T-C)}{b} \) (Dhanoa, 1988) where \( A, B \) and \( c \) are as described above and \( k \) is the rumen outflow rate, assumed to be 0.02h\(^{-1}\), 0.05 h\(^{-1}\), 0.08 h\(^{-1}\) (Ørskov et al., 1988).

**Chemical analysis**

DM was determined by oven drying the samples to a constant weight at 105°C. Ash was determined by igniting the dry samples in a muffle furnace at 525°C for 8 h. The concentration of nitrogen (N) content was measured using the Kjeldhal method (AOAC, 1990). CP was calculated as N x 6.25. NDF and ADF contents were determined by the method of AOAC (1990). The value of ME, Ca and P of mixture for feedstuff was determined by the method of Yang (1999).

**Statistical analysis**

Statistical significance of the difference between forages species was tested using Duncan’s mean Multiple Comparison Test (SAS, 1985).

**Results and discussion**

Chemical compositions of the forages are presented in Table 1. The CP values of forages ranged from 11.35 to 20.22%, NDF ranged from 36.19 to 65.53%, ADF from 15.06 to 29.66%, and crude ash from 4.35 to 11.3 %. Differences in the composition of the forages were apparent. *C.satakeana* had the highest CP content among the forages and *E.nutans* also had a higher CP level compared with the other forages. The CP values reported here are higher than those reported by Long et al. (1999) for *Catrofusca* (12.6%) and *E.nutans* (11.94%) when harvested at August. The significant differences in CP content may be due to increased age at harvest. The average CP content of other species was 13.12%. Similarly, Minson (1990) reported that the average crude protein content is about 13% for cool-season grasses. *K.myosuroides* had the highest NDF and ADF content. The variation in nutrient composition of all of the forages could be primarily attributed to varieties of these forage types.

Data on DM, CP and NDF degradation characteristics of forages are presented in Table 2. The washing loss (\( A_{w} \)) ranged from 0.214 g.g\(^{-1}\) in *K.myosuroides* to 0.417 g.g\(^{-1}\) in *L.humilis*. The range for soluble DM may be attributed to differences in non-structural carbohydrate content. *C.satakeana* tended to have higher insoluble but fermentable fraction (\( B_{w} \)) than all the other varieties. The ‘\( a \)’ value for DM and NDF in *L.humilis* was higher (P<0.01) than for the other forages. The washing loss (\( A_{w} \)) varied from 0.169 g.g\(^{-1}\) in *Pansa- rinia* to 0.3 g.g\(^{-1}\) in *C.satakeana*. A more rapidly degradable CP fraction was apparent for *K.myosuroides*, *C.satakeana* and *Pansa- rinia*. The average ‘\( a \)’CP of all eight samples was 0.123 g.g\(^{-1}\), which is lower than the findings reported by Balde et al. (1993) for Enneas (<0.25 g.g\(^{-1}\)). *K.humilis* had the highest fractional rates of NDF degradation (c) to DM and CP. *Pansa- rinia* had the highest fractional rates of NDF and CP decomposition (c); however, it had lower fractional rates of NDF than the other forages. The average DM was much lower than that reported by Balde et al. (1993) for orchardgrass (0.050 h\(^{-1}\)). The average CP was also much lower than reported for other cool season grasses; for example, by Beever and Siddons (1986) who estimated CP degradation rates of 0.09 to 0.14 h\(^{-1}\) for perennial ryegrass and by Kaya et al. (2004) for pasture samples (0.056 h\(^{-1}\)). Similar significant effects of the forage species on the degradation rate of CP were also indicated by Hoffman et al. (1993). Species and time of harvesting differences may explain some of these observed dissimilarities among the findings of

### Table 1. Chemical composition of forages used for in situ experiment.

| Species       | Crude protein % DM | NDF % DM | ADF % DM | Ash % DM |
|---------------|---------------------|----------|----------|----------|
| *C.satakeana* | 20.22               | 48.94    | 20.96    | 6.98     |
| *K.myosuroides* | 11.54             | 65.53    | 29.66    | 4.35     |
| *K.humilis*   | 13.99               | 55.63    | 18.33    | 6.99     |
| *L.humilis*   | 11.35               | 36.19    | 19.76    | 8.10     |
| *Pansa- rinia*| 12.08               | 36.48    | 18.84    | 9.72     |
| *Salienera*   | 13.31               | 60.81    | 18.50    | 11.30    |
| *Pansa- na*   | 16.47               | 54.46    | 23.94    | 6.76     |
| *E.nutans*    | 17.44               | 62.13    | 15.06    | 5.74     |
these various studies.

Table 2 shows the effective DM, CP and NDF degradability were calculated by using rumen outflow rates of 0.02, 0.05 and 0.08 h⁻¹. The effective degradability values decreased with increased outflow rates. Significant differences (P<0.01) were observed between forages for effective degradability of DM, CP and NDF. The highest effective degradability of DM was recorded in L. humilis (0.665 g·g⁻¹) and the lowest in F. pratensis (0.397 g·g⁻¹) at a 0.02 h⁻¹ passage rate. Similar effect of forages species on the effective degradability of DM was also indicated by Susmel et al. (1990) and Turgut and Yanar (2004). Grazing of N rich forages in combination with grasses, particularly in the summer months, should help in meeting the requirements for rumen degradable protein and should improve animal performance (Long et al., 1999). Further work is needed to estimate degradability of the native forages harvested from different regions at different seasons and establish optimum levels of inclusion of native forages in livestock diets to optimize grassland use and animal performance.

### Table 2. DM, CP and NDF degradation characteristics and effective degradability values of forages.

| Types of forages | A (g·g⁻¹) | a (g·g⁻¹) | b (g·g⁻¹) | B (g·g⁻¹) | A+B (g·g⁻¹) | c (h⁻¹) | L (h) | Effective degradability (g·g⁻¹) |
|------------------|-----------|-----------|-----------|-----------|-------------|---------|------|-------------------------------|
|                  |           |           |           |           | k=0.02h⁻¹   | k=0.05h⁻¹| k=0.08h⁻¹ |
| DM degradability |           |           |           |           |             |         |      |                               |
| C.satakeana      | 0.334     | 0.142     | 0.765     | 0.573     | 0.907       | 0.02    | 14.4 | 0.621                         |
| K.myosoroides    | 0.214     | 0.077     | 0.677     | 0.54      | 0.754       | 0.015   | 15.1 | 0.445                         |
| KHumilis         | 0.265     | 0.176     | 0.559     | 0.468     | 0.733       | 0.024   | 7.5  | 0.52                          |
| L.humilis        | 0.417     | 0.313     | 0.599     | 0.405     | 0.912       | 0.02    | 9.5  | 0.665                         |
| Panansina        | 0.273     | 0.204     | 0.292     | 0.223     | 0.496       | 0.025   | 10.5 | 0.537                         |
| Saliena          | 0.223     | 0.177     | 0.335     | 0.289     | 0.512       | 0.034   | 4.3  | 0.405                         |
| Panana           | 0.294     | 0.069     | 0.508     | 0.283     | 0.577       | 0.053   | 11   | 0.499                         |
| E.nutans         | 0.264     | 0.095     | 0.672     | 0.502     | 0.766       | 0.027   | 10.8 | 0.552                         |
| SE               | 0.0231    | 0.0285    | 0.059     | 0.0477    | 0.0579      | 0.004   | 1.24 | 0.0344                        |
| CP degradability |           |           |           |           |             |         |      |                               |
| C.satakeana      | 0.3       | 0.149     | 0.412     | 0.262     | 0.562       | 0.036   | 12.6 | 0.468                         |
| K.myosoroides    | 0.1882    | 0.093     | 0.314     | 0.218     | 0.406       | 0.038   | 9.55 | 0.331                         |
| KHumilis         | 0.2366    | 0.15      | 0.45      | 0.364     | 0.6         | 0.033   | 6.5  | 0.463                         |
| L.humilis        | 0.2114    | 0.128     | 0.533     | 0.47      | 0.681       | 0.023   | 7.1  | 0.463                         |
| Panansina        | 0.1933    | 0.148     | 0.391     | 0.37      | 0.539       | 0.02    | 2.8  | 0.354                         |
| Saliena          | 0.181     | 0.111     | 0.389     | 0.319     | 0.5         | 0.034   | 5.8  | 0.382                         |
| Panana           | 0.188     | 0.106     | 0.467     | 0.385     | 0.573       | 0.039   | 4.9  | 0.442                         |
| E.nutans         | 0.2946    | 0.095     | 0.672     | 0.472     | 0.766       | 0.027   | 13.1 | 0.566                          |
| SE               | 0.0181    | 0.0086    | 0.0394    | 0.0318    | 0.0387      | 0.003   | 1.294| 0.0267                        |
| NDF degradability|           |           |           |           |             |         |      |                               |
| C.satakeana      | 0.2055    | 0.053     | 0.69      | 0.538     | 0.743       | 0.019   | 13.2 | 0.467                         |
| K.myosoroides    | 0.0991    | 0.061     | 0.695     | 0.567     | 0.666       | 0.022   | 3    | 0.396                          |
| KHumilis         | 0.1142    | 0.063     | 0.686     | 0.635     | 0.749       | 0.029   | 2.6  | 0.49                           |
| L.humilis        | 0.2501    | 0.175     | 0.598     | 0.523     | 0.773       | 0.014   | 9.6  | 0.465                          |
| Panansina        | 0.2617    | 0.177     | 0.566     | 0.461     | 0.743       | 0.017   | 12   | 0.494                          |
| Saliena          | 0.1237    | 0.042     | 0.491     | 0.409     | 0.533       | 0.063   | 2.9  | 0.434                          |
| Panana           | 0.16      | 0.144     | 0.374     | 0.358     | 0.518       | 0.019   | 2.3  | 0.334                          |
| E.nutans         | 0.2158    | 0.122     | 0.383     | 0.289     | 0.506       | 0.028   | 10   | 0.385                          |
| SE               | 0.0238    | 0.0199    | 0.0377    | 0.0429    | 0.0405      | 0.006   | 1.709| 0.0149                         |

DM, Dry matter; CP, Crude protein; NDF, Neutral detergent fibre; A, washing loss; a, rapidly degradable fraction; b, slowly degradable fraction; B, insoluble but fermentable fraction; A+B, potential degradability; c, degradation rate of B (fraction/h); L, lag phase (h); Effective degradability at an outflow rate of 0.02h⁻¹, 0.05 h⁻¹ and 0.08 h⁻¹.

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