Effects of feeding lambs fresh versus dried *Puccinellia tenuiflora* (Griesb.) Scribn. & Merr. on water and nutrient intake and apparent digestibility

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The objective was to investigate effects of feeding lambs fresh versus dried *Puccinellia. tenuiflora* (Griesb.) Scribn. & Merr. on nutrient and water intake and apparent digestibility. Twenty-four lambs were offered fresh or dried (48 h) grass. The dry matter (DM) content of fresh grass was 65% that of dried grass and the aNDFom content of fresh grass was 87% that of dried grass, whereas the metabolizable energy concentration of two forages were similar. Lambs eating fresh grass had higher (*P < 0.05*) DM intake (944 vs 837 g DM d\(^{-1}\) sheep\(^{-1}\)), metabolizable energy intake (9.1 vs 7.9 MJ d\(^{-1}\) sheep\(^{-1}\)), and crude protein intake (86 vs 75 g d\(^{-1}\) sheep\(^{-1}\)) than those eating dried grass. However, there was no significant difference between treatments in drinking water intake, fecal nutrient output or nutrient digestibility. In conclusion, feeding lambs fresh *P. tenuiflora* improved voluntary feed intake without depressing nutrient digestibility.

**KEYWORDS**
forage composition; nutrient partitioning; water intake

1 INTRODUCTION

*Puccinellia tenuiflora* (Griesb.) Scribn. & Merr. has an outstanding tolerance to highly alkaline and saline soil and it is commonly grown for ruminants to graze or eat as conserved forage. Although salt-responsive mechanisms underpinning the growth of *P. tenuiflora* in high alkali and saline soil conditions have been reported, there have been few publications evaluating feeding value and digestive characteristics of *P. tenuiflora* in ruminants. Feeding fresh vs dried forage to ruminants has altered feed intake, digestibility and liveweight gain performance (Archimède et al., 1999; Pasha, Prigge, Russel, & Bryan, 1994), but the nature and extent of responses seemed inconsistent (Andrade et al., 2016; Pasha et al., 1994). Furthermore, effects of moisture content of the grass on water
intake were not investigated in these studies. Therefore, the aim of this study was to investigate the effects of feeding fresh or dried *P. tenuiflora* on nutrient and water intake and digestibility by sheep.

2 MATERIALS AND METHODS

All procedures involving the use of animals were approved by the Animal Care Committee of the Institute of Geography and Agroecology, Chinese Academy of Sciences (#2016001). *P. tenuiflora* grass was harvested in a six year old paddock with high salinity and alkaline soil, located in a semi-arid region in Changchun, China (44°33'N, 123°31'E). Twenty-four male Ujumqin lambs (mean ± SD) 120 ± 10.5 d of age and 29 ± 0.8 kg of body weight (BW) were assigned to one of two dietary treatments (fresh vs. dried grass), in a completely randomized design. Both treatments had a 7-d adaptation and a 7-d measurement period. Lambs were kept in individual metabolism cages (1792 × 790 × 1615 mm) and offered the grass and water *ad libitum*. Lambs were fed fresh harvested grass in two equal-sized meals at 0600 and 1800 h, whereas dried grass treatment lambs were offered grass that had been air-dried (at 25–35 °C for 48 h).

Daily grass and water intake per lamb were estimated from the difference between supply and refusal. Daily grass sample was collected and stored at -20 °C for chemical analyses. A subsample of grass was dried in a forced air oven at 65 °C for 48 h to determine the DM content and then ground through a 1-mm sieve for organic matter (OM) (AOAC, 1990; 968.06) and nitrogen (N) analysis (AOAC, 1990; 976.05). The content of neutral detergent fiber excluded ash (aNDFom) was determined as described (Van Soest et al. 1991).

Total amount of feces and number of defecations were recorded on a daily, with 168 fecal samples collected and combined for each lamb. Fecal samples from five lambs per treatment were used for chemical analyses. Fecal samples were dried in a forced air oven at 65 °C for 48 h to determine DM content and then ground to pass a 1-mm screen for N, aNDFom and OM analysis (same methods as described above). Digestibility for DM, OM, aNDFom and N were calculated. Metabolizable energy (ME) concentration of grasses was calculated: ME (MJ/kg DM) = 0.156 × Apparent DMD (%) – 0.535 (AAC, 1994).
Differences between treatments in DM intake (DMI), water intake, fecal output and digestibility were analyzed by one-way ANOVA, with treatment as the fixed effect, using GenStat 16 (VSN International, 2011). For all analyses, $P < 0.05$ was significant.

3 | RESULTS AND DISCUSSION

The DM content of fresh grass was 65% that of dried grass ($570 \text{ vs. } 871 \text{ g DM kg}^{-1} \text{ fresh matter}$), whereas the aNDFom content of fresh grass was 87% that of dried grass ($383 \text{ vs. } 438 \text{ g kg}^{-1} \text{ DM}$). However, CP ($90 \text{ vs. } 91 \text{ g kg}^{-1} \text{ DM}$) and OM ($822 \text{ vs. } 803 \text{ g kg}^{-1} \text{ DM}$) content did not differ markedly between the forages.

Fresh grass treatment had a higher ($P < 0.05$) intake that the dried grass treatment for DM ($944 \text{ vs. } 837 \text{ g DM d}^{-1} \text{ sheep}^{-1}$), ME ($9.1 \text{ vs. } 7.9 \text{ MJ d}^{-1} \text{ sheep}^{-1}$) and CP ($86 \text{ vs. } 75 \text{ g d}^{-1} \text{ sheep}^{-1}$). Feed water intake ($712 \text{ vs. } 124 \text{ ml d}^{-1} \text{ sheep}^{-1}$) and daily water intake ($2791 \text{ vs. } 1857 \text{ ml d}^{-1} \text{ sheep}^{-1}$) were higher ($P < 0.05$) in lambs eating fresh as compared with dried grass. However, there were no differences ($P > 0.05$) between treatments in OM, aNDFom, drinking water intake, digestibility and fecal output of DM, OM, CP and aNDFom.

The DM content of $P. tenuiflora$ is relatively higher than that of other grass species (Archimède et al., 1999; Pasha et al., 1994). Dried forage has 53% higher DM and 14% higher aNDFom content than fresh forage, and 11% lower DMI in lamb fed dried forage than fresh forage in the present study were similar to the findings of Archimède et al. (1999), who compared consumption of dried versus fresh $Poa pratensis$ and $Digitaria decumbens$ grass in sheep. In contrast, there was a 12% reduction in DMI when sheep were offered high-moisture forage ($220 \text{ g DM kg}^{-1} \text{ fresh matter}$) than those which were offered hay ($870 \text{ g DM kg}^{-1} \text{ fresh matter}$) (Pasha et al., 1994). These inconsistencies have several potential causes: 1) as DMI is limited by maximum rumen fill, the higher water content in fresh grass may lead to the decrease in DMI through a physical regulation. However, such effects can be transitory and subject to increase of water outflow rate from the rumen (Estrada, Delagarde, Faverdin, & Peyraud, 2004). 2) In this study, lamb eating the fresh grass defecated more often ($P = 0.033$) and excreted more water in feces ($P = 0.025$) than those eating dried grass. Extra water ingested from fresh grass would have been at least partly excreted via feces, thereby counter-balancing rumen fill (Allison,
124 1985). Future research is needed to explore the actual mechanisms that regulate DMI in
125 consumption of fresh vs dried forage.
126
127 The increased DMI was associated with an increased daily water intake of lambs in
128 this study, which is consistent with general observations in sheep, goats and cattle studies
129 (AAC, 1994). Higher water intake can reduce DM accumulation in the digestive tract of
130 ruminants (Phillips, 1960), reducing apparent nutrient digestibility (Balch, Balch,
131 Johnson, & Turner, 1953). On the contrary, due to the effect of the ruminal mat, the forage
132 with greater NDF (i.e. dried grass) can cause longer rumen retention time and leading
133 higher apparent digestion coefficients (Schulze, Weisbjerg, Storm, & Nørgaard, 2014).
134 However, in the present study, there was no significant difference between diets in
135 apparent digestibility of nutrients (i.e. DM, OM, aNDFom and CP).
136
4 CONCLUSIONS

138 Overall, feeding fresh P. tenuiflora improved DM and nutrient intake without altering
139 DM or nutrient digestibility. This finding is useful to guide future use of P. tenuiflora in
140 ruminant animal production.

ACKNOWLEDGMENTS

143 This work was financially supported by the National Key Research and Development
144 Program (Grant No. 2016YFC0500606) and the Youth Innovation Promotion
145 Association of the Chinese Academy of Sciences (No. 2015184).

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TABLE 1 Effects of feeding fresh and dried *Puccinellia tenuiflora* grass on intake, fecal output, digestibility and estimated metabolizable energy in sheep.

<table>
<thead>
<tr>
<th></th>
<th>Fresh grass</th>
<th>Dried grass</th>
<th>SEM</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>DM intake (g DM/d)</td>
<td>944</td>
<td>837</td>
<td>33.2</td>
<td>0.033</td>
</tr>
<tr>
<td>ME intake (MJ/d)</td>
<td>9.1</td>
<td>7.9</td>
<td>0.41</td>
<td>0.043</td>
</tr>
<tr>
<td>CP intake (g/d)</td>
<td>86</td>
<td>75</td>
<td>3.0</td>
<td>0.021</td>
</tr>
<tr>
<td>aNDFom intake (g/d)</td>
<td>361</td>
<td>367</td>
<td>14.3</td>
<td>0.800</td>
</tr>
<tr>
<td>OM intake (g/d)</td>
<td>758</td>
<td>688</td>
<td>27.2</td>
<td>0.084</td>
</tr>
<tr>
<td>Fecal water output (g/d)</td>
<td>834</td>
<td>673</td>
<td>47.5</td>
<td>0.025</td>
</tr>
<tr>
<td>Fecal DM output (g DM/d)</td>
<td>327</td>
<td>303</td>
<td>15.2</td>
<td>0.28</td>
</tr>
<tr>
<td>Fecal OM output (g/d)</td>
<td>286</td>
<td>271</td>
<td>19.2</td>
<td>0.583</td>
</tr>
<tr>
<td>Fecal aNDFom output (g/d)</td>
<td>136</td>
<td>135</td>
<td>8.9</td>
<td>0.948</td>
</tr>
<tr>
<td>Fecal CP output (g/d)</td>
<td>43</td>
<td>42</td>
<td>3.5</td>
<td>0.862</td>
</tr>
<tr>
<td>Defecation frequency (times/d)</td>
<td>15.5</td>
<td>13.2</td>
<td>0.48</td>
<td>0.003</td>
</tr>
<tr>
<td>Drinking water intake (ml/d)</td>
<td>1579</td>
<td>1733</td>
<td>88.6</td>
<td>0.231</td>
</tr>
<tr>
<td>Feed water intake (ml/d)</td>
<td>712</td>
<td>124</td>
<td>9.7</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Daily water intake (ml/d)</td>
<td>2291</td>
<td>1857</td>
<td>90.5</td>
<td>0.003</td>
</tr>
<tr>
<td>DM digestibility (%)</td>
<td>65</td>
<td>64</td>
<td>1.4</td>
<td>0.392</td>
</tr>
<tr>
<td>OM digestibility (%)</td>
<td>50</td>
<td>51</td>
<td>1.4</td>
<td>0.695</td>
</tr>
<tr>
<td>aNDFom digestibility (%)</td>
<td>63</td>
<td>65</td>
<td>1.5</td>
<td>0.458</td>
</tr>
<tr>
<td>CP digestibility (%)</td>
<td>51</td>
<td>47</td>
<td>2.5</td>
<td>0.314</td>
</tr>
<tr>
<td>ME† (MJ/kg DM)</td>
<td>9.7</td>
<td>9.4</td>
<td>0.22</td>
<td>0.392</td>
</tr>
</tbody>
</table>

Abbreviations: DM, dry matter; ME, metabolizable energy; CP, crude protein; aNDFom, neutral detergent fiber (exclude ash); OM, organic matter.

† ME (metabolizable energy) concentration: ME (MJ/kg DM) = 0.156 × Apparent DMD (%) – 0.535.
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Title:
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Date:
2021-10

Citation:

Persistent Link:
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