INTRODUCTION

Shrubs, a component of ruminant diet, play an important role in the nutrition of grazing animals (Holechek 1984; Meuret et al. 1990; Papachristou and Nastis 1996). At present Pakistan is deficient by 40 and 80% in forage and concentrate feeds, respectively (Pasha 1998). Moreover, the existing feed resources are providing only 62 and 74% of the required crude protein (CP) and total digestible nutrients (TDN), respectively, resulting in low productivity of livestock in the country (Sarwar et al. 2009).

Shrubs offer a potential alternative forage source for small ruminants in tropical countries especially during periods of scarcity when both quality and quantity of fodder is scarce. In addition to grasses and legumes, shrubs are widely available and inexpensive source of feed for small ruminants. Therefore, shrubs being valuable supplements providing variety to grasses and have considerable potential in supporting economical animal production in developing countries (Devendra 1989), moreover, their addition in ruminant diet can help to minimize the wide gap between availability and supply of nutrients, resulting in improved livestock productivity.

Little information regarding the nutritive value of shrubs widely used for small ruminants in hilly areas of the country are available, therefore, present study was conducted to envisage the nutritional evaluation of shrubs by their chemical composition, mineral profile, palatability and in vitro digestibility.

MATERIALS AND METHODS

Collection of samples: Leaves of Indigofera gerardiana, Marisine africana, Impashion bicolor and Adhatoda vesica shrubs were collected from valley of Chaghanzai, district Bunair, North Trans-Himalayan zone, Malakand Division, North West Frontier Provence, Pakistan. Five shrubs of each species were sampled. Approximately 1 kg leaves sample was harvested from each species as a single sample harvested from a shrub. Thereafter, composite sample of leaves was prepared for each species. The leaf samples were dried in an oven (Mommert, Germany) at 55°C for 48 h and saved in polythene bags.

Chemical analysis: The samples of shrubs species were ground through 2 mm screen in Willey mill and analyzed for dry matter (DM), N, ash (AOAC 1995), neutral detergent fiber (NDF), acid detergent fiber (ADF) and acid detergent lignin (ADL; Van Soest et al. 1991). The CP was calculated as CP= N x 6.25. Hemicellulose was determined by difference of NDF and ADF. Following the wet digestion (nitric acid and perchloric acid), Na was determined by the flame photometer (Jenway PFP7, UK).
The Ca, P, Mg, Cu, Co, Mn and Zn were determined by atom absorption spectrophotometry (model 4; Perkin-Elmer, Norwalk, CT, USA). All chemical analyses were done in triplicate.

**Palatability:** Four mature sheep (average body weight 40 kg) were used to determine palatability. The sheep were adapted for 5 weeks to the mixture of dry leaves of selected shrubs and trained in the experimental procedure by offering test samples to them alone or in pairs daily. During preliminary period, animals were fed a mixed diet of 80% dry leaves and 20% concentrate (10% CP and 8.37 MJ/kg ME) along with mineral mixture to meet sheep requirements (NRC, 1985). The potential intake rate and relative preference for different shrub leaves was determined by the procedure of Sultan et al. (2007). Leaves of each shrub species were offered to sheep for a set of comparisons consisting of 4 consecutive periods of 1 minute duration at 10 minute intervals. Sufficient feed was offered in plastic containers to ensure that residues remained after one minute of intake. After a delay of 1 h, a new set of comparisons was started with a maximum of 4 sets in a day. Positioning of the containers of forages in a pair were reversed for each successive offering to avoid left- or right-hand bias. The preference for a particular forage was determined by the standard procedure developed by Bell (1959) for 2-choice tests, as the intake of shrub leaves expressed as a percentage of the combined intake of both test and standard forage. Relative preference = [(amount of test forage eaten) / (amount of test + standard forage eaten)] x 100

**In vitro dry matter digestibility and metabolizable energy:** Oven-dried ground samples (0.5g) were incubated at 37±1°C for 48 h at pH 6.7-7.0 in an all-glass system using 45 mL of inoculum. The inoculum consisted of 36 mL of McDougal`s artificial saliva and 9 mL of strained fresh rumen liquor collected from ruminally fistulated sheep (fed diverse shrubs and grasses and supplemented with concentrate). After incubation and centrifugation, the residue was treated for 48 h with pepsin in weak acid. All incubations were carried out in triplicate with a blank (without sample). The final residue was composed of undigested plant cell wall and bacterial debris and yield values were supposed to be comparable to in vivo apparent digestibility (Tilley and Terry 1963). In vitro DM digestibility (IVDMD) was determined by the method described by Sultan et al. (2007). The metabolizable energy (ME) was determined by the following equation (Sultan et al, 2008): ME (MJ/kg DM)= 0.15 IVDMD% whereas, in vitro organic dry matter digestibility (IVOMD%) = 0.98 IVDMD% - 4.8

**Statistical analysis:** The data collected on chemical composition, mineral profile, in vitro DM digestibility, ME, potential intake rate and relative preference were analysed using analysis of variance in a completely randomized design and means were compared by least significant difference test (SPSS, 1999).

**RESULTS AND DISCUSSION**

**Chemical composition:** Chemical composition of shrubs is presented in Table 1. The DM contents varied from 24.3 (A. vesica) to 38.1% (I. gerardiana, I. bicolor). Highest CP concentration (23.7%) was observed for M. africana, while, lowest CP concentration (15.6%) was noticed for I. bicolor and A. vesica. The NDF contents varied from 49 (M. africana) to 64% (I. bicolor). Lowest ADF (22%) was observed for I. bicolor, whereas highest (37%) for I. gerardiana. Hemicellulose ranged from 21 (A. vesica) to 42% (I. bicolor). Lignin contents varied between 4.6 (I. gerardiana) to 7.9% (I. bicolor). Highest (14.7%) ash contents were noticed for M. africana and lowest (10.2%) for A. vesica. The chemical composition of shrubs species analyzed here provides a good source to be used as the nutrient source of ruminant feed.

**Mineral profile:** Mineral profile of shrubs is presenten in Table 2. The Ca contents varied from 1.01 for A. vesica to 2.7% for I. bicolor and were higher than the dietary requirements of dairy cattle (0.43-0.60% of DM of diet) recommended by NRC (2001). However, ruminants can tolerate Ca up to 2% of diet DM (NRC 1985). The P contents ranged from 0.016 in I. bicolor to 0.064% in M. africana. The values of P observed in this study were lower than the maximum value (0.38%) of P examined for most of tree leaves reported earlier (Mandal 1997) and were also lower than the dietary requirements of dairy cattle (0.31-0.40% of DM of diet) recommended by NRC (2001). The P in shrubs was low (0.071-0.085%) in comparison with the required minimum of 0.20% (McDowell et al., 1984). The Ca:P ratio in I. gerardiana, M. africana, I. bicolor and A. vesica was much wider (30.48, 15.94, 168.75 and 16.56, respectively) compared to those recommended for ruminants (McDowell 1997), however, this factor can be overcome by feeding cereal byproducts supplemented diets containing low Ca and high P (Prakash et al. 2009). Ruminant can tolerate Ca:P ratio as wide as 7:1 (NRC 1985). Rogosic et al. (2006) observed wide Ca:P ratio among shrub species. Saha and Gupta (1987) reported that tree are rich in Ca and poor in P. High Ca:P ratio reduces absorption of P (NRC 2001). Therefore, P supplementation appears to be essential (Breves and Schroder, 1991). Durand and Komisarczuk (1988) reported that available P should be at least 5 g/kg organic matter digested to optimize degradation of cell walls by microbes. Concentration of Ca >1% have been associated with lower DM intake, and excess Ca can interfere with trace mineral absorption (especially Zn) and lower performance of dairy cattle (NRC 2001). The K value...
was highest in *I. bicolor* (1.29%) and lowest (0.47%) in *I. gerardiana*. Dietary requirement of K for dairy cattle is 0.80% of diet on DM basis (NRC 2001). Maximum tolerable level of K is 3% diet DM (NRC 1980). Increasing the level of K from 0.7 to 3% linearly decreased the energy and weight gain in lambs (NRC 1985). The Mg contents varied from 0.012 (M. affricana) to 0.032% (*I. bicolor*) and were lower than the required level (0.12-0.18% of diet DM) of Mg for sheep (NRC 1985). The Cu contents ranged from 14 (A. vesica) to 25 ppm (*I. bicolor*) and were below the toxic level as Underwood (1981) reported that Cu concentration as low as 40 ppm can cause toxicity in sheep if level of Mo and S are low in the diet; however, cattle are more tolerant. Dietary requiremenets of Cu is 10mg/kg (NRC 1985) and 0.2-7mg/kg (Church 1988). The Cu values determined for shrubs in this study were higher than required level. Sheep requirement for Zn varied between 20-33 mg/kg of diet DM (NRC 1985). The Zn contents of *I. gerardiana*, *M. affricana* and *A. vesica* (17.6, 12.4 and 18.4 ppm, respectively) were lower than the required level, whereas, the Zn content (41.3 ppm) of *I. bicolor* was higher than the recommended level, however, this may be controlled by its high level of Ca as it affect the Zn utilization (Mills and Dalgarno, 1967). Less variation was observed in Mn contents among *I. gerardiana*, *M. affricana*, *I. bicolor* and *A. vesica* shrubs. However, Mn values observed in this study were lower than the recommended level (20mg/kg of diet DM) for sheep (NRC 1985). The Co contents ranged from 0.012 ppm for *I. bicolor* to 0.061 ppm for *I. gerardiana* and were lower than recommended level (0.1mg Co/kg diet DM) for sheep (NRC, 1985). Inam-ur-Rahim et al. (2008) observed 0.001 to 0.02 ppm Co concentrations in mature marginal land grasses and reported that the concentrations were below the recommended requirements for livestock. Vercoe (1987) analyzed mineral contents of 23 tree species used for livestock feeding and reported range of Ca, 0.29-3.52%; P, 0.05-0.18%; K, 0.41-1.78%; Mg, 0.21-0.62%; Cu, 4-152 ppm; Zn, 22-123 ppm and Mn, 30-917 ppm. In present study, Ca, K and Cu values were within the range as reported by Vercoe (1987), however, Mg and Mn values were below this range.

**Palatability:** Potential intake rate (g/sheep/4min) was highest (64.5) for *I. gerardiana* while, lowest (8.8) for *A. vesica* (Table 3). Similar results were observed regarding relative preference. Potential intake rate and relative preference are considered the main indicators for palatability (Rehman 1995; Sultan et al. 2007). Potential intake rate is affected by degree of tenderness, while, relative preference is influenced by chemical factors (Sultan et al. 2007; Rahim et al. 2008). Lower potential intake rate in for *I. bicolor* and *A. vesica* might be due to the presence of any antinutritional factor having particular taste and smell (Rehman, 1995). Sheep preferred diet having faster intake rates when the effects of taste and odor were removed (Kenney and Black 1984).

**In vitro dry matter digestibility and metabolizable energy:** Highest in vitro DM digestibility (69.7%) and ME (9.54 MJ/kgDM) were observed for *I. bicolor* (Table 3). Whereas, lowest in vitro DM digestibility (53.5%) and ME (7.16 MJ/kgDM) were examined for *A. vesica*. The higher ME contents of *I. bicolor* than other shrub species might be due to its higher (69.7%) in vitro DM digestibility. Lower in vitro DM digestibility of *A. vesica* might be due to the presence of any antinutritional factor which inhibit the rumen microbial enzymes (Moore and Jung, 2001; Sultan et al., 2007).

### Table 1. Chemical composition of shrubs (%)

<table>
<thead>
<tr>
<th>Shrub species</th>
<th>DM</th>
<th>CP</th>
<th>NDF</th>
<th>ADF</th>
<th>HC</th>
<th>Lignin</th>
<th>Ash</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>I. gerardiana</em></td>
<td>38.1</td>
<td>16.6</td>
<td>61</td>
<td>37</td>
<td>24</td>
<td>4.6</td>
<td>10.6</td>
</tr>
<tr>
<td><em>M. affricana</em></td>
<td>36.2</td>
<td>23.7</td>
<td>49</td>
<td>23</td>
<td>26</td>
<td>5</td>
<td>14.7</td>
</tr>
<tr>
<td><em>I. bicolor</em></td>
<td>38.1</td>
<td>15.6</td>
<td>64</td>
<td>22</td>
<td>42</td>
<td>7.9</td>
<td>12.4</td>
</tr>
<tr>
<td><em>A. vesica</em></td>
<td>24.3</td>
<td>15.6</td>
<td>56</td>
<td>35</td>
<td>21</td>
<td>5.2</td>
<td>10.2</td>
</tr>
</tbody>
</table>

DM: dry matter, CP: crude protein, NDF: neutral detergent fiber, ADF: acid detergent fiber, HC: hemicellulose

### Table 2. Minerals composition of shrubs

<table>
<thead>
<tr>
<th>Shrubs</th>
<th>Ca, %</th>
<th>P, %</th>
<th>Ca:P</th>
<th>K, %</th>
<th>Mg, ppm</th>
<th>Cu, ppm</th>
<th>Zn, ppm</th>
<th>Mn, ppm</th>
<th>Co, ppm</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>I. gerardiana</em></td>
<td>1.28</td>
<td>0.042</td>
<td>30.48</td>
<td>0.47</td>
<td>0.014</td>
<td>20</td>
<td>17.6</td>
<td>9</td>
<td>0.061</td>
</tr>
<tr>
<td><em>M. affricana</em></td>
<td>1.02</td>
<td>0.064</td>
<td>15.94</td>
<td>0.71</td>
<td>0.012</td>
<td>18</td>
<td>12.4</td>
<td>11</td>
<td>0.029</td>
</tr>
<tr>
<td><em>I. bicolor</em></td>
<td>2.7</td>
<td>0.016</td>
<td>168.75</td>
<td>1.29</td>
<td>0.032</td>
<td>25</td>
<td>41.3</td>
<td>10</td>
<td>0.012</td>
</tr>
<tr>
<td><em>A. vesica</em></td>
<td>1.01</td>
<td>0.061</td>
<td>16.56</td>
<td>0.56</td>
<td>0.023</td>
<td>14</td>
<td>18.4</td>
<td>12</td>
<td>0.053</td>
</tr>
</tbody>
</table>
The results revealed regarding chemical composition, high availability of ME, \textit{in vitro} DM digestibility and palatability, shrub species for use as ruminant feed are ranked as \textit{M. africana} > \textit{I. gerardiana} > \textit{I. bicolor} > \textit{A. vesica}. A wider Ca to P ratio suggests supplementing cereal byproducts having high level of P along with these shrubs when fed to ruminants. The concentration of P, Mg Mn and Co among these shrub species were less than required level. Further research is needed to evaluate these shrubs for any antinutritional factor.

**REFERENCES**


### Table 3. \textit{In vitro} digestibility and metabolizable energy, potential intake rate and relative preference

<table>
<thead>
<tr>
<th>Shrub species</th>
<th>IVDMD</th>
<th>ME</th>
<th>PIR</th>
<th>PR</th>
</tr>
</thead>
<tbody>
<tr>
<td>\textit{I. gerardiana}</td>
<td>57.8\textsuperscript{b}</td>
<td>7.78\textsuperscript{b}</td>
<td>64.5\textsuperscript{a}</td>
<td>73.18\textsuperscript{a}</td>
</tr>
<tr>
<td>\textit{M. africana}</td>
<td>57.1\textsuperscript{b}</td>
<td>7.66\textsuperscript{c}</td>
<td>53.0\textsuperscript{b}</td>
<td>66.35\textsuperscript{b}</td>
</tr>
<tr>
<td>\textit{I. bicolor}</td>
<td>69.7\textsuperscript{a}</td>
<td>9.54\textsuperscript{a}</td>
<td>34.0\textsuperscript{c}</td>
<td>43.8\textsuperscript{c}</td>
</tr>
<tr>
<td>\textit{A. vesica}</td>
<td>53.5\textsuperscript{c}</td>
<td>7.16\textsuperscript{d}</td>
<td>8.8\textsuperscript{d}</td>
<td>2.63\textsuperscript{d}</td>
</tr>
<tr>
<td>Standard error</td>
<td>2.65</td>
<td>0.33</td>
<td>2.29</td>
<td>2.6</td>
</tr>
</tbody>
</table>

IVDMD: in vitro dry matter digestibility (%), ME: metabolizable energy (MJ/kg DM), PIR: Potential intake rate (g/sheep/4mintues), RP: Relative preference (%).

\textsuperscript{abcd}Means in a row with different superscripts differ significantly (P < 0.05).

**Conclusion**: The results revealed regarding chemical composition, high availability of ME, \textit{in vitro} DM digestibility and palatability, shrub species for use as ruminant feed are ranked as \textit{M. africana} > \textit{I. gerardiana} > \textit{I. bicolor} > \textit{A. vesica}. A wider Ca to P ratio suggests supplementing cereal byproducts having high level of P along with these shrubs when fed to ruminants. The concentration of P, Mg Mn and Co among these shrub species were less than required level. Further research is needed to evaluate these shrubs for any antinutritional factor.
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