Nutritional uniformity of neutral detergent solubles in some tropical browse leaf and pod diets

C.M. Shayo,*, P. Udén

aZonal Research and Training Centre, Livestock Production Research Institute,
P.O. Box 202, Mpwapwa, Tanzania
bDepartment of Animal Nutrition and Management, Swedish University of Agricultural Sciences,
P.O. Box 7024, S-750 07, Uppsala, Sweden

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Abstract

An experiment was conducted to study the nutritional uniformity of neutral detergent solubles (NDS) in tropical browse species comprising Faidherbia albida, Acacia tortilis, Delonix elata and Mulberry (Morus alba) leaves and F. albida, A. tortilis, A. nilotica and Dichrostachys cinerea pods. The browse supplements were fed together with maize bran to individually caged goats at increasing levels in hay-based diets. Each diet had five levels of the browse feeds in duplicate which were randomly allocated to the goats in five periods of 14 days each. Chemical composition of the feeds consumed and faeces voided were determined. Nutritional uniformity (Lucas test) of NDS was determined for individual browse by regressing the digestible amount upon its content in the dry matter, in which the regression slope represents true digestibility and the y-intercept, endogenous excretions.

A. nilotica pods and A. tortilis and D. elata leaves were not well accepted by the animals, due to the high levels of phenolic compounds and mould. There was no significant (p > 0.05) relationship between the estimated amount of digested NDS and content of phenolic compounds in the browses. True digestibilities of NDS were significantly (p < 0.05) different between the species. The y-intercepts were not significantly (p > 0.05) different from zero for all species except F. albida leaves (−7.89). The true digestibility (±SD) of NDS for all the species combined in the Lucas test was 91.9 ± 0.03% and the metabolic matter was estimated at 3.38 ± 1.13 g/100 g of dry matter intake. The variable true NDS digestibility among the species was an indication of non-uniformity of this fraction, implying that the digestibility of the NDS fraction of tropical browse species may not be predicted from its content. Further studies to include more species are necessary to determine if this is a general phenomenon with tropical browse species. © 1999 Elsevier Science B.V. All rights reserved.

Keywords: Tropical browse; Digestibility; Neutral detergent solubles; Lucas/uniformity test
1. Introduction

The use of simple laboratory methods that can predict nutritive value by the content of nutrients in the forages is of great practical and economic importance. According to Lucas (1964), a rational system of feed analysis could be developed if feed fractions could be found for which the indigestible or digestible amounts could be predicted from their composition. A reliable prediction of the digestible amount will depend on the uniform availability of the nutrient fraction in question. A feed fraction which has the same true digestibility irrespective of level and origin is considered nutritionally uniform (Van Soest, 1994) and may be estimated by the Lucas equation (Lucas, 1964), in which the digestible fraction per unit of the feed is regressed upon its concentration in the feed. The regression slope in the Lucas test represents true digestibility and the intercept, endogenous excretions.

The neutral detergent soluble fraction of feeds is considered to be completely available (Van Soest, 1994). However, the NDS fraction is comprised of sugars, soluble carbohydrates, pectins, non-protein nitrogen, proteins, lipids and other solubles (Van Soest, 1994), some of which (e.g. proteins and carbohydrates) may react with tannins to form unavailable complexes (Nastis and Malechek, 1981; Zucker, 1983). A high proportion of the phenolics is also soluble in neutral detergent reagent, and therefore may not be digested by the animal. Tannins occur in many browse species (Reed et al., 1985; Reed, 1986; Mueller-Harvey et al., 1987), and can result in non-uniformity of the NDS fraction. To confirm this, an in vivo study was conducted with some browse leaves and pods.

2. Materials and methods

2.1. Animals and feeds

The trial was conducted at the Livestock Production Research Institute, Mpwapwa, in central Tanzania using 16 male goats weighing between 14 and 32 kg (mean = 20.8 kg). Prior to commencement of the experiment, all goats were sprayed against ectoparasites and drenched against endoparasites. Initially, 14 days were allowed for the animals to become acclimatised to the test feeds. The diets were comprised of hay and supplements. The supplements consisted of maize bran (MB) and browse leaves or pods. The browse leaves came from Faidherbia albida, Acacia tortilis, Delonix elata and mulberry (Morus alba) trees, and the pods were from F. albida, A. tortilis, A. nilotica and Dichrostachys cinerea trees. A. nilotica pods, and A. tortilis and D. elata leaves were harvested two years before they were used in this study, whereas the other browse supplements were harvested and stored for a period of less than six months. The hay comprised mainly Rhodes grass (Chloris gayana), Cynodon spp and Buffel grass (Cenchrus ciliaris). Incorporation of maize bran was necessary as the goats would otherwise not consume some of the supplements, particularly the ground pods if fed alone. Each diet had five levels of the browse feeds in duplicate and they were randomly allocated to the goats in five periods. Except for Level 0, MB formed
50% of the amount of the browse offered. Level 0 had a small amount of MB, which should not have been included. Daily amount of the supplements (maize bran + browse) in each level was calculated based on the animal’s body weight (BW), and were 7.5, 15, 22.5 and 30 g/kg of the animals’ BW for levels 1, 2, 3, and 4, respectively. Hay offered was calculated such that total feed offered (supplements + hay) would make up to 40 g/kg BW per day plus an allowance of 20% of hay as refusals. The goats were randomly allocated to the treatments in an unbalanced design and were not blocked for weight. It was assumed that differences in goat weight would not result in a significant variation in the digestibility of a particular feed type. Actual amounts (g/kg BW) of hay, maize bran and browse supplements provided are shown in Table 1. Although the diets in Level 0 were offered throughout the trial, the values for these were excluded from analyses.

2.2. Feeding and data collection

After the acclimatisation period, the goats were fitted with faecal collection bags and caged individually. During the 14-day experimental period, the goats were provided with hay and the supplements (treatments). In each experimental period, there was a preliminary period of seven days, followed by seven days of data collection, and between each experimental period the animals were removed from the cages for 10 days. Water and mineral block were accessible to the animals throughout the experimental period. Each morning, at 8.00 h, the animals were provided with the test diets. The pods and the MB were fed in a mixture, whereas the leaves and the MB were fed separately, starting with MB followed by the leaves. Hay was provided immediately after consumption of the test feeds. However, some supplements were not completely consumed even after 6 h. Refused supplements were removed at 14.00 h, weighed, and the animals provided with hay. Each morning, at 7.30 h, hay refusals from the previous day for each animal were removed and weighed. About 10% of the refusals were sub-sampled for dry matter (DM), organic matter (OM) and neutral detergent fibre (NDF). Faeces were collected in the bags attached to the rear of the animal. Faecal collection bags were emptied twice a day during the data collection period, weighed and 10% deep frozen for laboratory analyses.
2.3. Laboratory analyses

DM, ash and CP contents of the feed samples and faeces were determined according to the procedures of AOAC (1985), and NDF and acid detergent fibre (ADF) according to Van Soest et al. (1991). The neutral detergent soluble fraction (NDS) was calculated on OM basis and hemicellulose (Hem) was calculated as the difference between NDF and ADF. Total phenolics were determined by the Folin–Ciocalteu method as described by Waterman and Mole (1994). The extract was further diluted to 0.1 mg DM/ml. Absorbance was read at 740 nm through a 1-cm cuvette.

2.4. Mathematical analyses

The true digestibilities of the NDS fraction and the metabolic contributions for individual diets and all the diets combined were determined by regressing the digested amount of NDS upon its percentage in the DM (Lucas, 1964).

The estimated true digestibilities were compared using a one-way analysis of variance for differences between the species. For the species which showed significant differences, the means were compared using Tukey’s procedure at \( p < 0.05 \). To establish whether the content of phenolic compounds had influenced NDS digestibility, the estimated true digestibility of NDS for individual species was regressed upon the content of phenolic compounds.

2.5. Results and discussion

The chemical compositions of the feeds used in the present study are shown in Table 2. Except for *F. albida* and *D. elata* leaves, which had about 20% of CP, the

<table>
<thead>
<tr>
<th>Feedstuff</th>
<th>Ash (% of DM)</th>
<th>CP (% of OM)</th>
<th>NDF</th>
<th>NDS</th>
<th>ADF</th>
<th>Hem</th>
<th>Total soluble phenolics(b) (740 nm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mulberry leaves</td>
<td>12.8</td>
<td>13.2</td>
<td>23.5</td>
<td>63.7</td>
<td>20.4</td>
<td>3.1</td>
<td>32.8</td>
</tr>
<tr>
<td><em>Acacia tortilis</em> pods</td>
<td>5.9</td>
<td>14.1</td>
<td>31.8</td>
<td>62.3</td>
<td>26.6</td>
<td>5.2</td>
<td>53.8</td>
</tr>
<tr>
<td><em>Faidherbia albida</em> pods</td>
<td>4.4</td>
<td>11.8</td>
<td>36.2</td>
<td>59.4</td>
<td>28.8</td>
<td>7.4</td>
<td>79.3</td>
</tr>
<tr>
<td><em>F. albida</em> leaves</td>
<td>5.5</td>
<td>19.2</td>
<td>35.4</td>
<td>59.1</td>
<td>25.3</td>
<td>10.1</td>
<td>46.8</td>
</tr>
<tr>
<td><em>Dichrostachys cinerea</em> pods</td>
<td>6.3</td>
<td>10.4</td>
<td>40.4</td>
<td>53.3</td>
<td>32.5</td>
<td>7.9</td>
<td>106.8</td>
</tr>
<tr>
<td><em>A. nilotica</em> pods</td>
<td>5.8</td>
<td>10.7</td>
<td>22.2</td>
<td>72.0</td>
<td>17.2</td>
<td>4.6</td>
<td>294.8</td>
</tr>
<tr>
<td><em>Delonix elata</em> leaves</td>
<td>7.5</td>
<td>21.6</td>
<td>52.9</td>
<td>39.6</td>
<td>31.1</td>
<td>21.8</td>
<td>108.7</td>
</tr>
<tr>
<td><em>A. tortilis</em> leaves</td>
<td>6.4</td>
<td>12.8</td>
<td>45.6</td>
<td>48.0</td>
<td>43.1</td>
<td>2.5</td>
<td>118.2</td>
</tr>
<tr>
<td>Maize bran</td>
<td>2.7</td>
<td>10.1</td>
<td>33.4</td>
<td>63.9</td>
<td>8.7</td>
<td>24.7</td>
<td>na(c)</td>
</tr>
<tr>
<td>Hay</td>
<td>5.7</td>
<td>2.8</td>
<td>73.5</td>
<td>15.4</td>
<td>49.4</td>
<td>24.1</td>
<td>na</td>
</tr>
</tbody>
</table>

\(a\) CP, crude protein; NDF, neutral detergent fibre; NDS, neutral detergent solubles; ADF, acid detergent fibre; and Hem, hemicellulose.

\(b\) Total soluble phenolic compounds presented as absorbance at 740 nm (units/100 mg DM/ml extract).

\(c\) Not available.
other supplements had moderate values (10–14%). However, the CP content of the browse species were higher than CP content in the basal diet in most grasses, particularly during the dry season (Gupta and Pradhan, 1975). Despite the high CP content, *A. nilotica* pods and *A. tortilis* and *D. cinerea* leaves were not well accepted by the animals. In many cases, the animals could not completely consume the amounts offered even after 6 h. Ground *A. nilotica* pods formed a ‘gum-like’ material in the mouths of the goats which seemed to reduce intake. The other supplements were completely consumed. Generally, ground pods took a longer time to finish as compared with leaves.

Since the indigenous browse species have co-evolved with predator populations of insects, bacteria, fungi and grazing animals they have developed defence mechanisms, such as chemical defence, which can be deterrent, toxic or reduce intake and digestibility. Tannins are known to reduce intake by various herbivores (Coley et al., 1985; Cooper and Owen-Smith, 1985; Ahn et al., 1989). *A. nilotica* pods and *A. tortilis* and *D. elata* leaves contained higher levels of phenolic compounds than the other browse species (except *D. cinerea* pods) and this could have been one of the reasons for their low intakes. There have been some studies also showing that intakes of *A. nilotica* pods by cattle, sheep and goats were lower than in pods of other browse species containing lower levels of phenolic compounds (Tanner et al., 1990; Shayo and Udén, 1998). The low acceptance of *A. tortilis* and *D. elata* leaves could also have been a result of mould developed on the leaves during storage, as they were harvested two years before they were used in this study. However, this was not the case in a study by Omar et al. (1998), who did not find any reduced intake of mouldy mulberry leaves by goats, which could probably be an indication that mould type may also be a factor.

The supplements had considerably higher NDS concentrations than the basal diet, resulting in an increase in the NDS content of the diet with level of supplementation (Table 3).

Relationships between the digested amount of NDS and its amount in the DM consumed (Lucas test) for individual species and for all species combined are shown in Table 4 and Fig. 1. However, *A. nilotica* pods, and *A. tortilis* and *D. elata* leaves were not considered in this aspect due to their low and inconsistent intakes.

The slopes of the regression equations in the Lucas test, which are estimates of the true digestibilities of NDS, were significantly \( (p < 0.05) \) different among the species.

### Table 3
Mean NDS (% of DM) in the browse, maize bran and hay diets consumed by goats

<table>
<thead>
<tr>
<th>Level</th>
<th>Feed</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>hay</td>
<td>maize bran</td>
</tr>
<tr>
<td>1</td>
<td>16.7</td>
<td>4.2</td>
</tr>
<tr>
<td>2</td>
<td>12.8</td>
<td>8.2</td>
</tr>
<tr>
<td>3</td>
<td>8.7</td>
<td>12.3</td>
</tr>
<tr>
<td>4</td>
<td>4.7</td>
<td>16.5</td>
</tr>
</tbody>
</table>

\(^a\) Mean of all the browse species.
Feed fractions showing variable digestibilities are regarded to be non-ideal (Van Soest, 1994). Although the NDS fraction of feeds is regarded as being almost completely available (Van Soest, 1994), the variability of the NDS fraction in the feeds tested could have been due to the effect of tannins, since they can react with carbohydrates, enzymes and proteins of the feeds to form indigestible complexes (Hagerman et al., 1992; Reed and Soller, 1987; Robbins et al., 1987). According to Reed et al. (1990), most complexes formed are not soluble in neutral detergent. As the complexes are recovered in the NDF fraction of the faeces, the proportion of NDS in the faeces is reduced, and thus the true digestibility value of the NDS is overestimated. Therefore, the presence of tannins in the diet may result in an elevated slope in the Lucas test. Reed et al. (1990) found that nitrogen in some tropical browse species was not nutritionally uniform due to the presence of tannins. However, the degree of precipitation of proteins depends on molecular weight and reactivity rather than content of the tannins (Kumar, 1983; Makkar et al., 1990; Hagerman et al., 1992). Probably, it is in this context that there was no significant ($p > 0.05$) relationship between the content of phenolic compounds in the feeds and the estimated true digestibility of the NDS fraction.

The findings in this study are in contrast with those of Van Soest (1967), Seoane (1982), Laforest et al. (1986) and Christen et al. (1990), who reported that NDS in some temperate legume and grass hays and silages were nutritionally uniform. However, in another Lucas test with some temperate grass and legume hays Aerts et al. (1978) did not find the cell contents to be nutritionally uniform. The authors obtained true digestibility values much greater than 100% and suggested that this might have resulted from increasing true digestibility of cell contents with increasing percentage of cell contents, or from a decrease of metabolic matter with increasing percentage of cell contents, or both.

In the present study, the metabolic amounts estimated from the Lucas test for the individual species except *F. albida* leaves were not significantly ($p > 0.05$) different from zero. The average metabolic fraction was lower (3.4 g/100 g of DM intake) than that reported by Van Soest (1967), Aerts et al. (1978), Laforest et al. (1986), Seoane (1982)

<table>
<thead>
<tr>
<th>Species</th>
<th>Slope a</th>
<th>Intercept</th>
<th>$R^2$ (%)</th>
<th>Standard deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>intercept</td>
</tr>
<tr>
<td><em>Faidherbia albida</em> pods</td>
<td>0.781a</td>
<td>1.76</td>
<td>95.8</td>
<td>2.91</td>
</tr>
<tr>
<td><em>Acacia tortilis</em> pods</td>
<td>0.968c</td>
<td>−4.76</td>
<td>98.6</td>
<td>1.98</td>
</tr>
<tr>
<td><em>Dichrostachys cinerea</em> pods</td>
<td>0.860b</td>
<td>−1.71</td>
<td>98.2</td>
<td>1.87</td>
</tr>
<tr>
<td><em>F. albida</em> leaves</td>
<td>1.042d</td>
<td>−7.89</td>
<td>98.9</td>
<td>2.09</td>
</tr>
<tr>
<td>Mulberry leaves</td>
<td>0.883b</td>
<td>−2.33</td>
<td>98.0</td>
<td>2.15</td>
</tr>
<tr>
<td>All species combined</td>
<td>0.919</td>
<td>−3.38</td>
<td>96.9</td>
<td>1.13</td>
</tr>
</tbody>
</table>

$^a$ Values in the same column followed by different letters are significantly different ($p < 0.05$).
and Christen et al. (1990) of 12.9, 17.0-23.8, 6.6, 12.7 and 13.3 g/100 g of DM intake, respectively. The reason for this difference is not clear.

3. Conclusions

This study has shown that NDS in some tropical browse is not a nutritionally uniform entity, suggesting that digestibility of the NDS fraction in tropical browse species

Fig. 1. Test of nutritional uniformity of neutral detergent soluble fraction in *Faidherbia albida* pods (a), *Acacia tortilis* pods (b), *Dichrostachys cinerea* pods (c), *F. albida* leaves (d), mulberry leaves (e) and all the species combined (f). SDa, standard deviation of the constant; SDb, standard deviation of the regression slope; RSD, residual standard deviation.

and Christen et al. (1990) of 12.9, 17.0-23.8, 6.6, 12.7 and 13.3 g/100 g of DM intake, respectively. The reason for this difference is not clear.
may not be predicted from its content. However, to confirm this, further work with more species is necessary to determine if this is a general phenomenon with tropical browse species.

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