Fodder value of three browse forage species for growing goats

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Abstract The study evaluated the effects of ad libitum feeding of foliages of Afzelia africana, Daniellia oliveri and Entada africana supplemented with concentrate in twenty-four intact growing bucks (6 mo old, live weight (LW) 7.30 ± 0.1 kg). Goats were divided into three equal groups of similar LW in a complete randomized design. Intakes of forage, dry matter (DM), crude protein (CP), nitrogen, organic matter (OM) and digestible crude protein (DCP), average daily gain, digestibilities of DM and CP, DCP, N retention, ruminal fluid acetate, and serum urea N, albumin and globulin were greater (P < 0.05; 0.01) in Afzelia or Daniellia vs. Entada. Digestible energy (DE) to DCP ratio was lower (P < 0.01) in Afzelia or Daniellia vs. Entada. Digestibility of OM, digestible OM, energy, microbial protein synthesis, ruminal volatile fatty acids and serum total protein were superior (P < 0.05) in Afzelia vs. Entada and in Daniellia vs. Entada. Digestibility of fibre fractions and ruminal NH3-N was lower (P < 0.05; 0.01) for Entada relative to Afzelia and Daniellia. Whereas ruminal fluid propionate was higher (P < 0.05; 0.01) for Daniellia compared to Afzelia or Entada, the acetate to propionate ratio was lower (P < 0.05; 0.01) in Daniellia than in Afzelia or Entada. Methane production was higher (P < 0.05) for Afzelia than for Daniellia or Entada. Serum glucose was greater in Daniellia than Afzelia (P < 0.05), in Afzelia than Entada (P < 0.05) and in Daniellia than Entada (P < 0.01). Results suggest Daniellia as an alternative fodder for Afzelia and indicate higher feeding value of Afzelia and Daniellia for feeding growing goats compared to Entada.

Abbreviations: ADF, acid detergent fibre; ADG, average daily gain; CP, crude protein; CT, condensed tannins; DCP, digestible crude protein; DE, digestible energy; DM, dry matter; DOM, digestible organic matter; FCR, feed conversion ratio; LW, live weight; ME, metabolizable energy; MPS, microbial protein synthesis; NDF, neutral detergent fibre; OM, organic matter; OMDR, organic matter digested in the rumen; VFA, volatile fatty acid

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1. Introduction

A major constraint to livestock production in developing countries is the scarcity and fluctuating quantity and quality of the year-round feed supply (Olafadehan and Adewumi, 2009). Consequently, the productivity of ruminant livestock in the tropics and subtropics is limited by inadequacy of good quality and nutritious feed. This becomes critical during the long dry season when the little available standing hay forages are lignified with adverse effects on voluntary intake, digestibility, productive and reproductive performance.

Browse fodders are useful sources of cheap feed for ruminant animals in developing countries, especially during dry seasons when herbaceous pasture grasses and legumes are senescence. Since they are able to retain their green leaves and nutrient content during dry seasons, they bridge the gap normally created by decline in the nutritive potentials of natural pastures during this period. The ability of their foliages to remain green and maintain their protein content makes them potential sources of protein and energy (Olafadehan, 2013).

Smallholder ruminant farmers in the developing countries cannot afford concentrates and thus depend almost entirely on browse fodders for feeding their stock. *Afzelia africana*, *Daniellia oliveri* and *Entada africana* are among the all year round available major leguminous browse plants in the savannah region of Nigeria (Okunade et al., 2014a). Both *A. africana* and *D. oliveri* belong to the family Caesalpinioideae, while *E. africana* belong to the family Mimosoideae. *A. africana* is increasingly used by livestock owners and preference of herders for it among other fodders has been documented (Bayer, 1990; Gautier et al., 2005; Ouédraogo-Konné et al., 2006) while the foliages are also sold in the cities for urban and peri-urban livestock production. Similarly, its superior fodder value in a cafeteria feeding trial (Okunade et al., 2014a), in vitro study (Okunade et al., 2014b) and in vivo study (Ouédraogo-Konné et al., 2008) has been reported. *A. africana* has thus attained the status of a conventional fodder in the developing countries. Due to its recognized fodder quality for livestock feeding, and timber value for furniture and building, the tree is heavily lopped and logged. Because of this problem, the tree is now an endangered species. There is, therefore, the need to evaluate the feeding value of other browse trees as alternative fodders. Information on fodder value of *D. oliveri* and *E. africana* is scanty in the literature and little or nothing has been done in search of alternative fodders to the endangered *A. africana*, to the best of our knowledge.

It was hypothesized that *A. africana* forage could improve the overall performance of goats compared to *D. oliveri* and *E. africana* forages, and *D. oliveri* could be a better alternative fodder compared to *E. africana*. The objective of this experiment was to evaluate the fodder value of *D. oliveri* and *E. africana* as alternative fodders to *A. africana* (conventional fodder) for growing goats.

2. Materials and methods

2.1. Animal management and diets

The study site has been described by Olafadehan et al. (2014a). Twenty-four intact Red Sokoto male goats (6 mo old, live weight (LW) 7.30 ± 0.1 kg) were housed individually in well-ventilated clean pens equipped with water and feed troughs. Before the experiment, all animals were given prophylactic treatments consisting of administration of antibiotics (Oxytetracycline), dewormed with albendazole and treated against ecto-parasites. An adaptation period of 2 weeks allowed the goats accustomed to the experimental diets and pen environment. At the end of the adaptation period, the goats were divided into three equal groups of similar LW, and groups were randomly assigned to one of three experimental fodders in a completely randomized design. Goats were weighted at the start of the experiment and weekly thereafter.

The diets consisted of fresh foliages of *A. africana*, *D. oliveri* and *E. africana* collected from several mature stands of the three browse fodders at pre-anthesis stage and carefully separated from the stem and petiole before being fed. Fresh foliages of the browse fodders were offered individually at 50 g DM/kg LW in two equal parts at 09:00 and 16:00 h. *Ad libitum* forage intake was ensured by making allowance for 500 g/kg of intake of previous day. A meagre quantity (100 g) of concentrate mixture (maize 100 g/kg, wheat bran 300 g/kg, palm kernel cake 200 g/kg, corn bran 300 g/kg, groundnut cake 50 g/kg, bone meal 40 g/kg, premix 50 g/kg and salt 50 g/kg) was offered approximately two hours before afternoon feeding of the fodders. The concentrate was consumed by all goats within 60 min of offer on all occasions. All animals had unrestricted access to water. Daily feed offered and ords were recorded and LW was measured weekly in the morning before feeding. The feeding and growth trials lasted for 84 days excluding the 2-week adaptation period.

2.2. Metabolism trial

Immediately after the feeding trial, six goats were randomly selected per treatment and transferred into metabolism cages. Measurements of daily intake, faeces and urine for 7 d were preceded by 10 d of adaptation to the cages. Fresh feeds, feed refusals and faeces were sampled daily for determination of dry matter (DM) and chemical analysis. Samples of feed offered, orts, faeces and urine voided were collected every morning. Samples of the faeces and urine (100 g/kg portion of daily production) were pooled for each animal for the 7 d period and sub-sampled for analysis. The DM of feed and faeces was determined by drying to a constant weight in a forced-air oven at 60 °C. The dried samples were ground to pass through a 1 mm screen and preserved for chemical analysis. Urine was collected in plastic containers containing 20 ml of concentrated sulphuric acids to prevent loss of N by volatilization. The samples were later frozen pending chemical analysis.

2.3. Rumen liquor collection

Rumen fluid samples were collected before the morning feeding on the last day of the experiment by aspiration using stomach tube. The pH was measured immediately after collection with a digital pH metre. The liquor was then strained through four layers of muslin cloth, preserved by adding 5 ml of 1 M H₂SO₄ to 45 ml of rumen fluid and subsequently frozen pending analysis.

2.4. Serum chemistry

Blood samples were collected once at the end of the feeding period by jugular puncture into serum tubes for biochemical
Three browse forage species assays. Blood samples were centrifuged at 1000 g for 20 min at 5 °C before storing at −20 °C.

2.5. Chemical analysis

Samples were analysed for dry matter (method 930.15), ash (method 924.05), crude protein (CP, Kjeldahl N × 6.25, method 984.13), ether extract (EE, method 920.39) and acid detergent fibre (ADF, method 973.18) by the procedures of AOAC (1990). Neutral detergent fibre (NDF) was determined using sodium sulphite but without a heat stable alpha amylase (Van Soest et al., 1991). Both NDF and ADF expressed were inclusive of residual ash. Ruminal ammonia samples were analysed for Kjeldahl-N according to AOAC (1990). Concentrations of volatile fatty acid (VFA) in the rumen liquor were analysed by gas chromatography and auto-analyser as described by Zijlstra et al. (1977). Condensed tannins (CTs) were determined by the methods of Makkar (2003) and expressed as gram equivalent leucocyanidins per kilogram DM. Total protein and albumin were estimated in serum (Wootten, 1964). Globulin was determined by subtracting albumin from total protein. Blood urea nitrogen was determined using commercial kit (Span diagnostics Ltd., New Delhi). Samples were analysed for glucose (Folin and Wu, 1920).

2.6. Statistical analysis and calculations

Data were subjected to the analysis of variance for a complete randomized design using SPSS Base 17 (SPSS software products, USA) with the following model:

\[ Y_{ij} = \mu + F_i + e_{ij} \]

where \( Y_{ij} \) is the dependent variable; \( \mu \) the general mean; \( F_i \) the effect of the \( i \)th forage species; and \( e_{ij} \) the residual error. Treatment comparisons were made using planned non-orthogonal contrasts, which included the following: (1) \( A. africana \) (control) vs. \( D. oliveri \); (2) \( A. africana \) vs. \( E. africana \); and (3) \( D. oliveri \) vs. \( E. africana \). Significant differences were declared if \( P < 0.05 \). Microbial protein synthesis was calculated as per Chen and Gomes (1995) equation:

Microbial N yield (MN) = 32 g/kg × organic matter digested in the rumen

\[ \text{Methane production was estimated using Moss et al. (2000) equation:} \]

\[ \text{CH}_4 \text{ production} = 0.5 \star (\text{acetate}) - 0.25 \star (\text{propionate}) + 0.5 \star (\text{butyrate}) \]

3. Results

3.1. Chemical composition of the diet

All browse species were high in CP, which was higher than that of the concentrate (Table 1). However, CP was greatest in Afzelia and lowest in Entada. Conversely, NDF was highest in Entada and least in Afzelia. Daniellia had slightly higher OM than Afzelia and Entada. The tree leaves were tannin-containing fodders, with highest and lowest concentrations in Entada and Afzelia, respectively.

| Table 1 | Chemical composition (g/kg DM) of browse fodder foliages and concentrate. |
|---------|-----------------------------|-------------|-----------------------------|
| Forage  | Concentrate                 |
| Afzelia | Daniellia                   | Entada      |
| Crude protein | 190 | 178 | 167 | 151 |
| Organic matter | 913 | 939 | 917 | 934 |
| Ash      | 116 | 120 | 126 | 65.6 |
| Neutral detergent fibre | 521 | 549 | 597 | 306 |
| Acid detergent fibre | 325 | 324 | 321 | 142 |
| Condensed tannins | 40.4 | 51.0 | 68.9 | ND |

ND, not detected.

3.2. Feed intake and performance of goats

Intakes of forage, total DM (g/d and g/kg W0.75), CP, OM and ADF, and final LW, LW gain and average daily gain (ADG) of Afzelia were similar (\( P > 0.05 \)) to those of Daniellia, but were lower (\( P < 0.01 \)) in Entada than in Afzelia or Daniellia (Table 2). Entada reduced (\( P < 0.05 \)) DM intake (g/kg LW) relative to Afzelia and Daniellia, which had similar (\( P > 0.05 \)) intake. Intakes of NDF and feed conversion ratio (FCR) were similar (\( P > 0.05 \)) for diets.

3.3. Total tract digestibility and nutritive value

Digestibilities of DM and CP, and digestible CP (DCP) were inferior in Entada (\( P < 0.01 \)) relative to Afzelia and Daniellia, which had similar (\( P > 0.05 \)) values (Table 3). Digestibilities of NDF and ADF did not (\( P > 0.05 \)) differ in Afzelia vs. Daniellia but were higher (\( P < 0.01 \)) in the two fodders than in Entada. While OM digestibility, digestible organic matter (DOM), digestible energy (DE) and metabolizable energy (ME) were similar (\( P > 0.05 \)) in Afzelia vs. Daniellia, they were superior (\( P < 0.05 \)) in Afzelia vs. Entada and in Daniellia vs. Entada (\( P < 0.01 \)). Ratio of DE/DCP was lower (\( P < 0.01 \)) in Afzelia and Daniellia vs. Entada and in Afzelia vs. Daniellia.

3.4. Plane of nutrition

Intake of DCP was greater (\( P < 0.01 \)) in Afzelia vs. Entada and in Daniellia vs. Entada but not (\( P > 0.05 \)) in Afzelia vs. Daniellia (Table 4). Intakes of DOM, DE and ME, and OMDR were not (\( P > 0.05 \)) different in Afzelia vs. Daniellia, but were greater (\( P < 0.05 \)) in Afzelia and Daniellia vs. Entada.

3.5. Nitrogen utilization and microbial protein synthesis

N Intake, absorption and retention were greater (\( P < 0.01 \)) in Afzelia or Daniellia than in Entada, but they were not (\( P > 0.05 \)) different in Afzelia vs. Daniellia (Table 5). Faecal N and N output were greater (\( P < 0.01 \)) in Afzelia vs. Daniellia and in Afzelia vs. Entada (\( P < 0.05 \)) but were marginal (\( P > 0.05 \)) in Daniellia vs. Entada. Urinary N was higher (\( P < 0.05 \)) in Afzelia compared to Daniellia but not
(P > 0.05) in Entada vs. Afzelia or Daniellia. Lower (P < 0.05) N balance occurred for the Entada vs. Afzelia or Daniellia, but it was similar (P > 0.05) for Afzelia vs. Daniellia. Entada reduced MPS compared to Afzelia (P < 0.01) or Daniellia (P < 0.05), whereas Afzelia vs. Daniellia had similar (P > 0.05) values.

3.6. Ruminal fermentation characteristics and methane production

Rumen liquor pH and butyrate were not (P > 0.05) affected by diet. NH₃-N was greater (P < 0.01) in Afzelia vs. Entada and in Daniellia vs. Entada (P < 0.05) but not (P > 0.05) in...
Afzelia vs. Daniellia (Table 6). Total VFA was similar (P > 0.05) for Afzelia vs. Daniellia but higher (P < 0.05) for Afzelia vs. Entada and Daniellia vs. Entada (P < 0.01). Ruminant acetate was similar (P > 0.05) for Afzelia vs. Daniellia but was lower (P < 0.05) for Entada than for Afzelia or Daniellia. Propionate concentration was superior for Daniellia compared to Afzelia (P < 0.05) and for Daniellia relative to Entada (P < 0.01) but not (P > 0.05) for Afzelia vs. Entada. While acetate:propionate ratio was higher in Afzelia vs. Daniellia (P < 0.05) and in Entada vs. Daniellia (P < 0.01), it was similar (P > 0.05) in Afzelia vs. Entada. Methane production was lower (P < 0.05) for Daniellia and Entada compared to Afzelia but was similar (P > 0.05) for Daniellia vs. Entada (see Table 7).

3.7. Serum chemistry

Serum urea N and albumin were greater in Afzelia vs. Entada and Daniellia vs. Entada but were not (P > 0.05) different in Afzelia vs. Daniellia. There was a reduction in serum glucose of Afzelia vs. Daniellia (P < 0.05), whereas glucose was higher in Afzelia vs. Entada (P < 0.05) and Daniellia vs. Entada.
Table 6 Rumen liquor characteristics and estimated methane production of goats fed browse fodder foliages.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Forage</th>
<th>SEM</th>
<th>Contrast</th>
<th>1</th>
<th>2</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH</td>
<td>Afzelia</td>
<td>6.8</td>
<td>6.8</td>
<td>6.9</td>
<td>0.09</td>
<td>NS</td>
</tr>
<tr>
<td>NH₃-N (mg/L)</td>
<td>Daniellia</td>
<td>171</td>
<td>156</td>
<td>156</td>
<td>5.68</td>
<td>NS</td>
</tr>
<tr>
<td>Total VFA (mmol/L)²</td>
<td>Entada</td>
<td>134</td>
<td>138</td>
<td>125</td>
<td>3.33</td>
<td>NS</td>
</tr>
<tr>
<td>VFA (mol/100 ml)</td>
<td>Acetate</td>
<td>77.0</td>
<td>76.7</td>
<td>72.1</td>
<td>1.55</td>
<td>NS</td>
</tr>
<tr>
<td>Propionate</td>
<td>18.5</td>
<td>22.8</td>
<td>16.1</td>
<td>11.1</td>
<td>1.11</td>
<td>**</td>
</tr>
<tr>
<td>Butyrate</td>
<td>10.5</td>
<td>9.67</td>
<td>9.37</td>
<td>1.01</td>
<td>0.22</td>
<td>NS</td>
</tr>
<tr>
<td>Acetate:propionate</td>
<td>4.2</td>
<td>3.4</td>
<td>4.5</td>
<td>0.22</td>
<td>0.22</td>
<td>NS</td>
</tr>
<tr>
<td>Methane production (mol/100 ml)</td>
<td>37.5</td>
<td>37.5</td>
<td>37.0</td>
<td>0.60</td>
<td>0.60</td>
<td>NS</td>
</tr>
</tbody>
</table>

NS, not significant (P > 0.05).
² VFA, volatile fatty acid.
* P < 0.05.
** P < 0.01.

Table 7 Serum biochemical constituents of goats fed browse foliage fodders.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Forage</th>
<th>SEM</th>
<th>Contrast</th>
<th>1</th>
<th>2</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Urea N (mmol/L)</td>
<td>Afzelia</td>
<td>10.1</td>
<td>9.0</td>
<td>6.4</td>
<td>0.89</td>
<td>NS</td>
</tr>
<tr>
<td>Glucose (mmol/L)</td>
<td>Daniellia</td>
<td>2.03</td>
<td>1.07</td>
<td>0.04</td>
<td>0.46</td>
<td>**</td>
</tr>
<tr>
<td>Total protein (g/L)</td>
<td>Entada</td>
<td>104</td>
<td>95.3</td>
<td>76.0</td>
<td>6.29</td>
<td>NS</td>
</tr>
<tr>
<td>Albumin (g/L)</td>
<td>Afzelia</td>
<td>41.0</td>
<td>43.0</td>
<td>37.8</td>
<td>1.39</td>
<td>NS</td>
</tr>
<tr>
<td>Globulin (g/L)</td>
<td>Daniellia</td>
<td>63.2</td>
<td>52.3</td>
<td>38.2</td>
<td>4.80</td>
<td>NS</td>
</tr>
<tr>
<td>Glucose (mmol/L)</td>
<td>Entada</td>
<td>1.21</td>
<td>2.03</td>
<td>1.07</td>
<td>0.46</td>
<td>NS</td>
</tr>
</tbody>
</table>

NS, not significant (P > 0.05).
* P < 0.05.
** P < 0.01.

(0.01). Serum total protein and globulin were similar (P > 0.05) for Afzelia vs. Daniellia but greater (P < 0.05; 0.01) for Afzelia vs. Entada and Daniellia vs. Entada.

4. Discussion

4.1. Chemical composition of the diet

The nutrient composition of foliages of the browse fodders is consistent with previous reports on tropical and subtropical tree fodders and shrubs (Prakash et al., 2009; Okunade et al., 2014a). The relatively higher CP and lower fibre and CTs contents of A. africana are suggestive of its superior nutritive value. However, the NDF concentrations of the browse fodders are below the range of 600-650 g/kg DM suggested as the limit above which intake of tropical feeds by ruminants would be limited (Van Soest et al., 1991). High CP and relatively lower fibre composition indicate the browse legume fodders potential as N supplements to ruminants fed on low quality roughage.

4.2. Feed intake and performance of goats

The greater DM intake of Afzelia and Daniellia forages compared to Entada is consistent with their higher CP, lower CT and lower NDF. There is a positive correlation of CP content and a negative correlation of fibre and CT with the voluntary feed intake (Alonso-Díaz et al., 2008; Khalid et al., 2012; Olafadehan et al., 2014a). The increased intake of CP and OM in Afzelia and Daniellia vs. Entada reflects the CP and OM concentrations of the fodders and the DM intake. Nutrient intake is generally a function of the concentration of the nutrient and DM intake. The improved LW gains of Afzelia and Daniellia vs. Entada were the consequence of their higher DM intake, CP content and intake, energy density and intake, digestibility and N utilization, in agreement with earlier findings (Olafadehan et al., 2014b). The results show superior nutritive value of Afzelia and Daniellia forage relative to Entada forage. However, the positive LW gains in all goats indicate that the three browse fodders supplied more than the goats’ maintenance CP and energy requirements which suggest the beneficial effects of the CT concentrations of the experimental fodders.

4.3. Total tract digestibility and nutritive value

In consistence with earlier findings (Foster et al., 2009), relative differences in DM intake and digestibility among the fodder legumes reflect partly the structural fibre concentrations and morphological characteristics of the browse fodders. Both Afzelia and Daniellia contained less NDF and more CP than Entada; consequently, the two forages were more digestible than Entada. Lower CP content and/or high fibre has been implicated for reduced digestibility (Olafadehan et al., 2014b). The lower nutritive value of Entada may be attributed to its relatively low intake, digestibility, DOM, DCP and energy which in association with its relatively high cell wall fibre and CTs possibly limit the activity of rumen microbes and consequently
microbial degradation. According to Olafadehan (2013), DOM and DCP are needed for enhancing the efficiency of rumen microbes for faster ruminal degradation and digesta outflow rate from the rumen for improved intake. Higher DE/DCP ratio of the Entada diet indicates that it required more DE per unit of DCP for optimization of feed utilization.

4.4. Plane of nutrition

In consistence with previous reports (Olafadehan et al., 2014b), greater intakes of digestible nutrients, OMDR and energy in Afzelia or Daniellia relative to Entada are occasioned by improved N utilization, voluntary intake, nutrients digestibility and nutritive value of the forages.

4.5. Nitrogen utilization and microbial protein synthesis

Afzelia and Daniellia increased N intake because of their greater CP concentrations and DM intake compared to Entada. N retention increased accordingly following the trend observed for N absorption. Parallel observations were made by Foster et al. (2009). Reduced N absorption, balance and retention of Entada suggest lower rate and extent of degradation of N from its leaves. This concurs with earlier reports on Barhar from its leaves. This concurs with earlier reports on Barhar Foster et al. (2009). Reduced N absorption, balance and retention of Entada suggest lower rate and extent of degradation of N from its leaves. This concurs with earlier reports on Barhar leaves (Das et al., 2011). In corroboration with previous findings (Melaku et al., 2004), the higher N output in Afzelia than in Daniellia and Entada suggests that Afzelia supplied more bypass protein than the animal could utilize. Microbial protein synthesis was increased by Afzelia and Daniellia because they provided more DOM intake, OMDR and energy for microbial growth than Entada. Low energy concentration of Entada could have resulted in reduced energy availability for incorporation of NH₃-N into microbial protein.

4.6. Ruminal fermentation characteristics and methane production

The NH₃-N level in all groups was above 150 mg/l recommended as minimum acceptable level for optimization of ruminal fibre degradation (Leng, 1990). Reduced rumen NH₃-N in Entada could be attributed to decreased N intake and protein degradation, in agreement with earlier reports (Ramos et al., 2009). Total ruminal VFA concentrations exceeded the normal range (100–120 mmol/L) in forage-fed ruminants (Bergman, 1990), reflecting the generally high degradability of the browse fodders. Lower total VFA of Entada than Afzelia and Daniellia reflects its reduced DOM intake, degradability, OMDR and consequently energy supply to the goats. Decrease in ruminal VFA formation has been reported to reduce energy supply to the host (Aschenbach et al., 2011). Daniellia appears to be more efficient in energy metabolism than Afzelia or Entada due to the higher production of propionate, which has a positive relationship with efficiency of energy utilization (Ramos et al., 2009). The reduced acetate production and OMDR observed for Entada diet might indicate relatively reduced ruminal fibre degradation and growth or activity of cellulolytic bacteria in Entada-fed goats. Lower methane production of Daniellia and Entada could be due to their relatively high CTs content compared to Afzelia. It appears that lower CTs and cell wall fibre of Afzelia enhanced its fermentability with concomitant increase in methanogenesis. Thus Daniellia and Entada could have a great potential in methane mitigation or reducing methanogenesis since ruminant livestock constitute worldwide the most important source of anthropogenic emissions of methane. Lowering global CH₄ emissions from enteric fermentation is an important part of any effort to reduce anthropogenic greenhouse gases emissions. The negative effect of CTs on methanogens resulting in decreased methane production has been reported (Wanapat et al., 2013, 2015).

4.7. Serum chemistry

Lower urea N of Entada is as a result of its decreased ruminal NH₃-N and relatively high CTs, which possibly affected its ruminal degradation. Olafadehan et al. (2014a) attributed increased plasma urea N to increased rumen NH₃-N concentration and reported negative correlation between urea N and CTs intake in goats fed varying forage:concentrate ratio. Higher serum glucose level of Daniellia relative to Afzelia and Entada is a reflection of its superior energy status due to its higher propionate level and VFA. The lower serum proteins of goats fed Entada indicate the inferior quality, level and availability of the forage protein, consistent with previous findings (Olafadehan, 2011).

5. Conclusion

The results of this study underscore the nutritive value of the three browse fodders and display the possibility of using them in smallholder ruminant production systems for sustainable and enhanced production. These three species should, therefore, be promoted in sylvopastoral systems. However, while D. oliveri can be used as an alternative fodder to the endangered A. africana, E. africana is less beneficial but can be used when Daniellia is not available. Daniellia is thus a promising fodder that can adequately substitute for the endangered A. africana.

Conflict of interest

The authors declare that they have no conflict of interest that could inappropriately influence, or be perceived to influence, the submitted work.

Authors’ contributions

O.A. Olafadehan conceived the study, participated in its design, corrected and revised the drafted manuscript. S.A. Okunade supervised the field work, analysed the data and drafted the manuscript. The two authors read and approved the final manuscript.

References
