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Nutritional properties of some browse species used as goat feed in Pastoral dry lands, Uganda

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Abstract The nutritional properties of leaves of ten browse species commonly used as goat feed in pastoral drylands of Uganda were evaluated by determining their chemical composition and in vitro gas production. Dry matter (DM) content ranged between 896 and 914 g kg^{-1} DM and was not significantly different ($P > 0.05$) among the browse species. There was a wide variation in the crude protein (CP) content of the browse species. The highest CP values were observed in *Acacia compylacantha*, *Acacia fruiticosa* and *Acacia senegal*, with 365, 247 and 245 g kg^{-1} DM respectively, while the lowest was observed in *Ganisa similis* (150 g kg^{-1} DM). The NDF values were highest in *A. senegal* (343 g kg^{-1} DM) and lowest in *A. compylacantha* (151 g kg^{-1} DM). There was no significant difference ($P > 0.05$) in the gas kinetics and total volume of gas produced by the browse species. The calculated organic matter digestibility (OMD) was highest ($P < 0.05$) in *Cadaba farinosa* (92.5%) and lowest in *Dichrostachys cinerea* (72.5%). Similarly, the metabolizable energy (ME) was highest ($P < 0.05$) in *C. farinosa* (13.7 MJ kg^{-1}) and lowest in *D. cinerea* (10.7 MJ kg^{-1}). Total gas had a positive correlation with OMD (r = 0.51, $P < 0.05$) and ME (r = 0.52, $P < 0.01$). Strong positive correlation was observed between OMD and ME (r = 0.998, $P < 0.001$). In conclusion, these browse species have sufficient CP and ME required by growing goats under dryland conditions.

Keywords Browse species · Pastoral · Drylands · Nutritive value · Goats

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Introduction

Goat production plays a significant role in the livelihoods of the pastoral communities (Kosgey et al. 2006). In such communities, goat production is largely extensive with goats relying on grazing natural pastures as their main feed resource (Reid et al. 2005). The quantity and quality of the pastures vary with season, becoming more fibrous and less nutritious especially during the dry season (Anele et al. 2009). The pastoral drylands are characterized with long dry seasons and short rain seasons. The livestock feeding systems are predominantly extensive with large herds of indigenous livestock that are freely grazed on large pieces of land. The livestock are moved from one place to another in search for water and pastures. The pastures are mainly native, can withstand the hot environment and are present in the wild. This kind of extensive feeding systems are slowly being eroded away due to the increasing population which in turn has caused conversion of grazing land into crop agriculture and housing to facilitate settlement (Cheema et al. 2011).This increases the potential for biodiversity loss of the nutritive pasture species that are currently present in the wild (Krauss et al. 2010), and indirectly causes a change from extensive feeding systems to semi-intensive and or intensive feeding systems—sedentary systems. The change in feeding systems requires the planting of domestic pasture species especially browse species with good nutritional value. Browse species have multiple functions (timber, shade, livestock and human medicine, food, etc.) (Nampanzira et al. 2015; Tabuti and Lye 2009) and some have the ability to remain green and maintain a high nutritive value longer in the dry season (Safari et al. 2011; Nampanzira et al. 2016). These properties make them preferred options in the development of dry season feeding strategies. Earlier studies have identified browse species consumed by goats in the dry pastoral areas (Muwanika et al. 2018). However, there is little information on the nutritional value of the browse species that are fed on by goats in the dry land pastoral areas of Eastern Africa. This information is valuable when choosing browse species to plant and include in the existing farming systems. The nutritive value of a ruminant feed is determined by the concentrations of its chemical components, as well as their rate and extent of digestion. In this study, the nutritional value of the priority browse species fed on by goats in Karamoja (Muwanika et al. 2018) was characterized. Karamoja is part of an extensive dry land pastoral system that covers nearly fifty percent of Eastern Africa. In this area, livestock keeping is the dominant livelihood activity. Additionally, the browse species included in this study are widely distributed in the extensive dryland areas of Africa

The objective of this study therefore was to characterize the nutritional value of the priority browse species consumed by the goats in the pastoral dry lands of Uganda.

Materials and methods

Location and climate of the study area

The study was conducted in pastoral areas of Karamoja sub region, in northeastern Uganda, located between 1° 4′–4.24° N and 33° 50′–35° E. The area is mostly semi-arid and experiences a single rainy season usually from April to August with a range from 400 to 1000 mm.

Collection of samples of browse species

Samples of browse species were collected from areas in the districts of Kaabong, Kotido and Moroto. Leaves were collected from ten browse species namely, *Acacia albida, Grewia mollis, Acacia senegal, Balanites aegyptica, Grewia simillis, Cadaba farinosa, Acalypha fruticosa, Ornocapum trichocarpum and Dichrostachys cinere* and *Acacia sieberiana*. The ten browse species are among the most common and preferred by farmers in the sub-region (Muwanika et al. 2018). The leaves were harvested during the period between April and June 2016. For each browse species, leaves were harvested from at least 3 randomly selected individuals. The harvested leaves for each species were composited, thoroughly mixed and thereafter two sub-samples were drawn. After collection, the samples were weighed (fresh weight) and placed in plastic bags, sealed, labeled placed in ice boxes containing ice, pending transportation to the laboratory for oven drying. After oven drying (at 60 °C for 48 h), the samples were weighed (dry weight) and divided into two sub-samples: one for chemical analysis and the other for in vitro digestibility determination.

In vitro gas production

Both particulate and liquid rumen fractions were collected from three goats fed on browse and grass, placed in an insulated thermos flask, sealed immediately and transported to the laboratory. Approximately 200 mg test feed samples ground to pass through a 1-mm screen were weighed and placed into the glass syringes of 100 mL. The rumen liquor was strained through two layers of cheese cloth under constant flushing with CO_2. The strained rumen fluid was poured into the buffer mixture of artificial saliva in a ratio of 1:2 and the mixture stirred using a magnetic stirrer. Samples were incubated in vitro with rumen fluid in calibrated glass syringes following the procedure of Menke and Steingass (1988). The rumen fluid-buffer mixture (30 mL) was then transferred into 100 mL glass syringes, incubated in a water bath at 39 °C (Plate 5.2) and gently shaken for 30 min immediately after the start of the incubation. Gas production was determined before incubation (0 h) and 2, 4, 6, 8, 10, 12, 24, 48, 72, 96 and 120 h after incubation. Three blank gas syringes containing only rumen fluid-buffer mixture were incubated alongside the samples. Net gas productions for browse samples were determined by subtracting the average blank gas volume from the observed gas production of each sample. The mean gas volume readings were fitted to the exponential equation $Y = a + b(1 - e^{-ct})$ (Orskov and McDonald 1979) to study the kinetics of gas production. The same equation was chosen to study the kinetics of gas production. This equation has been applied successfully to a variety of tropical forages, and the constants derived from this equation have been studied extensively.

$$Y = a + b(1 - e^{-ct}) \quad (1)$$

where y, total gas production at time *t*; *a*, gas production from the immediately fermentable OM (the intercept of the gas production curve); *b*, gas production from fermentation of the slowly but potentially fermentable OM; *a* + *b*, the potential gas production (the asymptote of the gas production curve); c, the rate constant for the gas production *b*; *t*, incubation time and e, base of natural logarithm (Blümmel and Ørskov 1993). The curve fittings were performed with the NLIN procedure of Statistical Analysis System (SAS 2003). The in vitro organic matter digestibility (OMD) and metabolizable energy (ME) contents of the samples were calculated from the net 48-h gas volume, CP and ash contents (Menke and Steingass 1988) according to the following equations:

$$\mathrm{OMD}\,(\%) = 14.88 + 0.889\mathrm{GV} + 0.45\mathrm{CP} + 0.0651\mathrm{XA} \quad (2)$$

$$\mathrm{ME}\,(\mathrm{MJ\ kg^{-1}\ DM}) = 2.20 + 0.136\mathrm{GV} + 0.057\mathrm{CP} \quad (3)$$

where GV, net gas volume at 48 h fermentation (mL g^{-1} DM); CP, crude protein content (g per 100 g DM) and XA, ash content (g per 100 g DM).

Chemical analysis

The samples designated for chemical composition were ground using a 1-mm screen. The samples were analyzed for CP and EE (AOAC 1990). NDF, ADF and ADL were determined according to Van Soest and Robertson (1985).

Statistical analysis

All data analyses were carried out using SAS (2003). The PROC MEANS procedure was used to compute means and standard deviations for chemical composition and ME. Comparison among species was carried out on chemical composition, in vitro gas production, OMD and ME with species as the main factor using the PROC GLM procedure with the model;

$$Y_{ij} = \mu + B_i + e_{ij};$$

where Y_{ij} is the independent variable, μ is the overall mean effect, B_i is the browse species effect and e_{ijk} is the random error. Significance between means was tested using the least significant difference (LSD). A Pearson correlation analysis was used to establish the relationship between chemical composition, in vitro gas production and calculated nutritive value.

Results

Chemical composition

The chemical composition of the browse species is summarized in Table 1.

The DM content ranged between 896 and 914 g kg^{-1} DM and was not significantly different ($P > 0.05$) among the browse species. There was a wide variation in the CP content of the browse species. The highest CP values were observed in *A. compylacantha, A. fruiticosa* and *A. senegal*, 365, 247and 245 g kg^{-1} DM respectively, while the lowest was observed in *G. similis* (150 g kg^{-1} DM). The NDF values were highest in *A. senegal* (343 g kg^{-1} DM) and lowest in *A. compylacantha* (151 g kg^{-1} DM). The browse species differed significantly ($P < 0.05$) in their ADL content. The highest values were recorded for *G.mollis* (214 g^{--1}kgDM) and *A. sieberiana* (206) where g kg^{-1} DM as the lowest value (98.0 g kg^{-1} DM) was observed in *A. senegal, O. trichocarpum* and *D. cinerea*.

Total gas production, organic matter digestibility and metabolizable energy contents

The gas production from 0 to 120 h was highest in *C. farinosa* and lowest in *D. cinera* (Fig. 1).

There was no significant difference ($P > 0.05$) in the gas kinetics and total volume of gas produced by

Table 1 Chemical composition (g kg^{-1} DM) of browse species from pastoral dry lands, Uganda

	DM (g/kg)	In g/kg DM					
		CP	NDF	ADF	ADL	ASH	EE
A. albida	909	365^{a}	151^{g}	269^{b}	147^{c}	125^{c}	27.5^{a}
G. similis	914	150^{f}	274^{e}	183^{e}	177^{b}	221^{a}	10.0^{d}
G. mollis	900	193^{cd}	294^{c}	311^{a}	214^{a}	171^{b}	9.9^{d}
A. senegal	905	245^{b}	343^{a}	191^{de}	98^{d}	72^{f}	15.0^{e}
B. aegyptica	922	178^{e}	315^{b}	196^{d}	146^{c}	121^{cd}	10.0^{d}
C. farinosa	896	195^{cd}	289^{cd}	160^{f}	167^{b}	130^{c}	19.9^{c}
A. fruticosa	900	247^{b}	231^{f}	16.0^{f}	180^{b}	111^{de}	5.0^{f}
O. trichocarpum	900	186^{de}	283^{de}	245^{c}	98.0^{d}	122^{cd}	24.9^{b}
D. cinerea	909	199^{c}	224^{f}	19.2^{de}	98.0^{d}	107^{e}	19.9^{c}
A. sieberiana	907	186^{de}	283^{de}	25.5^{c}	206^{a}	66.6^{f}	25.0^{b}
SEM	0.56	0.30	0.32	0.42	0.60	0.41	0.08
Level of significance	NS	***	***	***	***	***	***

NS not significant

***$P < 0.001$

^{abcdef}Means within rows with different superscripts are significantly different

the browse species. However, a significant ($P < 0.05$) difference in the calculated nutritive value was noted (Table 2). The total volume of gas produced after 24 h ranged from 48 mL g^{-1} OM (in *G. mollis*) to 64 mL g^{-1} OM (in *C. farinosa*).

At the end of the experiment after 120 h, the total gas volume varied from 61.3 mL g^{-1} OM (in *D. cinereal*) to 84.5 mL g^{-1} OM (in *C. farinosa*). There was no difference in the total gas kinetics. The gas production from the immediately fermentable OM (*a*) ranged between 35 (in *O. trichocarpum*) and 44.8 (in *A. senegal*). Gas production from fermentation of the slowly but potentially fermentable OM (*b*) was numerically higher in *O. trichocarpum* and lowest in *D. cinera.* The potential gas production ($a + b$) varied between 62.81 (*D. cinerea*) to 86.3 (*C. farinosa*). There was a significant difference $P < 0.05$) in the calculated OMD and ME of the browse species (Table 2). The Calculated OMD was highest ($P < 0.05$) in *C. farinosa* (92.5%) and lowest in *D. cinerea* (72.5%). Similarly, the ME was highest ($P < 0.05$) in *C. farinosa* (13.7 MJ kg^{-1}) and lowest in *D. cinerea* (10.6 MJ kg^{-1}). The NDF content was positively correlated with total gas (r = 0.174) and negatively correlated to CP (r = − 0.652, $P < 0.001$), OMD (r = − 0.263) and ME (r = − 0.218) Table 3. The CP content was negatively correlated with total gas (r = 0.06) but positively correlated with OMD (r = 0.379) and ME (r = 0.326). Strong positive correlation was observed between OMD and ME (r = 0.998, $P < 0.001$.

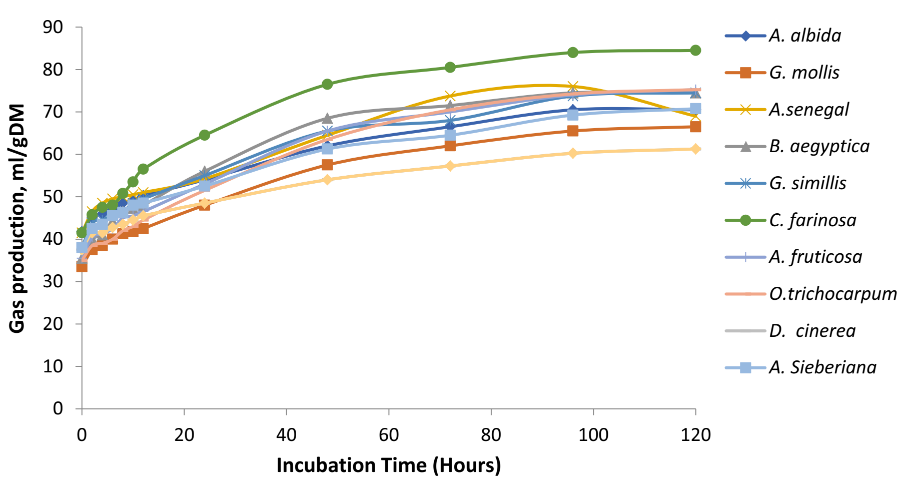

Fig. 1 Pattern of cumulative in vitro gas production (mL^{-1} g DM) on incubation time (h) of browse species in buffered rumen fluid

Table 2 In vitro gas production, total gas kinetics, organic matter digestibility (OMD) and metabolizable energy (ME) contents of forage samples from pastoral dry lands, Uganda

Browse species	Total gas (mL)		Total gas kinetics				OMD (%)	ME (MJ kg^{-1})
	24	120	a	b	c	a + b		
A. albida	54	70.5	43.3	30.5	0.02	73.8	87.2^{ab}	12.7^{ab}
G. mollis	48	66.5	35.2	34.3	0.02	69.5	75.8^{de}	11.1^{ef}
A. senegal	54	76.0	44.8	37.6	0.02	82.4	77.0^{de}	11.4^{def}
B. aegyptica	56	74.5	36.6	39.3	0.03	75.9	77.9^{cde}	11.5^{cdef}
G. similis	55	74.5	40.5	36.2	0.02	76.7	75.5^{e}	11.1^{ef}
C. farinosa	64	84.5	41.8	44.5	0.03	86.3	92.5^{a}	13.7^{a}
A. fruticosa	53	75.3	37.1	42.1	0.02	79.1	84.9^{bc}	12.5^{bc}
O. trichocarpum	52	75.3	35	50.9	0.02	85.9	80.5^{bcd}	11.9^{bcde}
D. cinerea	49	61.3	39.5	23.3	0.02	62.8	72.5^{e}	10.7^{f}
A. sieberiana	53	70.8	40.6	32.2	0.02	72.8	82.8^{bcd}	12.3^{bcd}
SE	4.22	7.02	3.79	6.56	0.004	8.08	2.27	0.35
P value	NS	NS	NS	NS	NS	NS	***	***

a, gas production from the immediately fermentable OM (the intercept of the gas production curve); b, gas production from fermentation of the slowly but potentially fermentable OM; a + b, the potential gas production (the asymptote of the gas production curve); c, the rate constant for the gas production

NS not significant

***$P < 0.001$

[abcdef]Means within rows with different superscripts are significantly different

Table 3 Pearson correlation coefficient (r) matrix of chemical composition (acid detergent fibre ADF, crude protein CP, OM) in vitro total gas and calculated nutritive value (OM digestibility and metabolizable energy, ME) of browse species from pastoral drylands, Uganda

	ADF	CP	Total gas	OMD	ME
NDF	− 0.482*	− 0.652***	0.174	− 0.263	− 0.218
ADF		0.556**	− 0.298	0.026	− 0.013
CP			− 0.06	0.379	0.326
Total gas				0.506*	0.519**
OMD					0.998***

*$P < 0.05$; **$P < 0.01$; ***$P < 0.001$

Discussion

Chemical analysis

The DM concentration observed for the ten browse species of 896–914 g/kg DM is in the range of that recorded in other studies conducted on similar native browse species in Eastern Africa (Abdulrazak et al. 2000; Berhane et al. 2006); Southern Africa (Tefera et al. 2008) and Western Africa (Sanon et al. 2008; Soliva et al. 2008). Generally, the DM of these browse species was high. This could be due to the late stage of maturity of the foliages at the time of collection, as the DM is known to increase with maturity of forage (Minson 1990). All the browse species in this study contained sufficient DM to support a reasonable amount of DM intake. According to Van Soest (1994), a DM range of 70–80 g/kg DM is suggested as the critical limit below which intake of forages by ruminants and rumen microbial activity would be adversely affected.

The CP values reported for *G. similis, B. aegyptica, C. farinose, G. mollis, A. sieberiana* and *D. cinereal* are within range of the CP values reported for similar species elsewhere (Goromela et al. 1997; Berhane et al. 2006; Soliva et al. 2008; Safari et al. 2011; Sebata et al. 2011). However, the CP value reported for *A. Albida* in the current study was higher than that previously reported by Addass et al. (2011). *Acacia senegal* recorded a CP value that was lower than that reported by Topps (1997), but higher than the value reported by Rubanza et al. (2005) in semi-arid parts of Tanzania. The difference in these CP values could be attributed to varied stages of maturity of the respective individual components of the samples (Al-Soqeer 2008; Anele et al. 2009). The CP values reported for all the browse species in this study are way beyond the 80 g/kg DM which is reported as the minimum recommended concentration required for maintenance of ruminant health and enhancing rumen microbial activity (Van Soest 1994). This suggests that these browse species are potential feed supplements for low-quality tropical roughage feeds (Soliva et al. 2008; Anele et al. 2009), which are characteristic of the pastoral drylands. CP is the major limiting nutrient in the diets of livestock in the drylands. Identifying alternative sources of CP that are naturally present in the communities at no or low cost is a positive step towards improving nutrition and hence productivity of livestock in the pastoral dry lands.

In the present study, the NDF values recorded for *G. similis, B. aegyptica* and C. *farinose* are within range of those reported by previous studies conducted elsewhere (Goromela et al. 1997; Berhane et al. 2006).

The NDF value of *A. albida* in this study was about 65% lower than that reported by Bouazza et al. (2012) and Boufennara et al. (2013). The NDF value for *A. senegal* in the current study is 30% higher than that reported by Abdulrazak et al. (2000) and Rubanza et al. (2005) but 50% lower than that reported by Sanon et al. (2008) and Topps 1997. Similarly, the NDF value for *A. sieberiana* was considerably lower than that reported in two previous studies (Soliva et al. 2008; Kaitho et al. 1998). Berhane et al. (2006) reported NDF value for *G. mollis* which is 47% higher than that reported in the current study. *Dichrostachys cinerea* recorded an NDF value which was twice lower than that reported in earlier studies by Sebata et al. (2011) and Berhane et al. (2006). The variation in the NDF values could be attributed to age and/or the physical composition differences of the leaves collected (Nampanzira et al. 2016). The NDF values of the browse species reported in this study 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 1994). Moderate fibre levels enhance colonization of ingesta by rumen microorganisms which in turn might induce higher fermentation rates, hence improving digestibility, intake and animal performance (Klopfenstein et al. 2001).

In vitro gas production, organic matter digestibility and energy contents

The rate constant for gas production (*c*) recorded in this study is within range of that reported by Anele et al. (2009) but lower than that reported by Bezabih et al. 2014. According to Blümmel and Becker (1997), the contribution of *c* to DMI prediction is limited but it is highly correlated with in vivo OMD (Chenost et al. 2001). The *c* value recorded in the present study shows that the browse species are highly digestible as the rate at which a feed or its chemical constituents are digested in the rumen is as important as the extent of digestion (Anele et al. 2009).

The (a + b) values reported in the present study is within range of those reported by earlier studies of browse species (Berhane et al. 2006). According to Chenost et al. (2001), there is a high positive correlation between the extent of gas production (a + b) with dry matter intakes and nutritive value of forages.

The OMD observed for these browse species is within range of that observed in previous studies about tropical browse species (Bezabih et al. 2014). *Dichrostachys cinera* recorded the lowest OMD in the present study. However, it is known that *D. cinerea* browse contain tannins (Mlambo et al. 2007, 2008), which may have negatively affected in vitro fermentation of *D. cinereal*. Forages having an OMD of 70% or more are considered to be of high quality (Meissner et al. 2000). This implies that all the browse species in this study are of a good quality.

The ME content of all the species in the present study is above the 9 MJ kg^{-1} DM, a level comparable with moderate quality forages (Leng 1990). The estimation of the ME values is very important in nutrition as it helps in ration formulation and to set economic value of feeds for other purposes (Getachew et al. 2002).

The positive correlation between NDF and in vitro gas production observed in the present study is comparable to studies conducted elsewhere for other browse species (Kumara Mahipala et al. 2009). There was a negative correlation between CP and the in vitro gas production. This trend is consistent with that observed by Getachew et al. (2004), Kumara Mahipala et al. (2009) and Bezabih et al. (2014). This trend however is contrary to the expected positive relationship between CP and in vitro gas production of grasses and browses (Kaitho et al. 1998; Datt et al. 2008). According to Kumara Mahipala et al. (2009), this negative effect could be due to high soluble-nitrogen content. This has been observed to reduce cumulative gas production at the early stages of incubation of substrates with rumen fluid (Cone and van Gelder 1999). Also, the expected high content of phenolic compounds in browse species could inactivate microbial enzymes and reduce protein degradation in the rumen (Kumar and Singh 1984).

Conclusion

The CP and calculated nutritive value of the browse species in the present study was relatively high. Therefore, these browse species present themselves as suitable options for inclusion in agro forestry-livestock production systems with an aim of improving the nutrition of livestock, while at the same time promoting sedentarisation of the pastoralists. However, further research on domestication potential of the browse species and effect of feeding these browse species on animal productivity is needed.

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Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

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