

The Nutritive Value and Palatability of Selected Browse Forages Mixtures from Arid and Semi-Arid Area of Kenya When Fed to Growing Small East African Goats

Isaac M. Osuga¹, Dennis G. Njeru², Levi M. Musalia² and Shaukat A. Abdulrazak³

¹Department of Animal Science, Jomo Kenyatta University of Agriculture and Technology, Nairobi,

²Department of Animal Science, Chuka University, Chuka, Kenya

³International Atomic Energy Agency, Vienna, Austria

Abstract

In this study the chemical composition, *in vitro* dry matter digestibility (IVDMD) and palatability of five browse forage mixtures were studied. The five forage mixtures were selected based on their nutritive value and IVDMD and from reported previous studies of single species. The species included *Acacia brevispica*, *Acacia mellifera*, *Acacia nilotica*, *Zizyphus mucronata* and *Berchemia discolor*. *In vitro* gas production technique was used to determine the rumen fermentation characteristics. Palatability of the browse forage mixtures was determined based on the mixture's voluntary intake by a cafeteria approach on growing small East African goats. The crude protein (CP) content ranged from 153.9 g/kg DM in *B. discolor* & *A. nilotica* forage mixture to 184.4 g/kg dry matter (DM) in *Z. mucronata* & *A. mellifera* forage mixture, while the total fibre content as measured by NDF ranged from 313.7 g/kg DM in *Z. mucronata* & *A. mellifera* forage mixture to 440.4 g/kg DM in the forage mixture containing *Z. mucronata*, *A. brevispica*, *A. mellifera* & *A. nilotica*. The IVDMD ranged from 57.1% in *B. discolor* & *A. nilotica* to 64.0% in the browse mixture containing *Z. mucronata*, *A. brevispica*, *A. mellifera* & *A. nilotica*. Browse mixture containing *Z. mucronata*, *A. brevispica*, *A. mellifera*, *A. nilotica* and mixture containing *B. discolor*, *Z. mucronata*, *A. mellifera* and *A. nilotica* were the most preferred by the animals and had a coefficient of preference (CoP) of 1.51 and 1.02 respectively. The two browse forage mixtures also had the highest ($p < 0.05$) intakes (168.6 and 113.3 g DMI/6h respectively) by the goats. The results of this study indicate that browse forage mixtures are highly palatable and have great potential as supplements for poor-quality basal diets in the marginal areas of the tropics and can enhance performance of livestock especially the small ruminants.

Key words: chemical composition, digestibility, *in vitro* gas production, palatability, supplementation

Date of Submission: 01-03-2020

Date of Acceptance: 28-03-2020

I. Introduction

The arid and semi-arid lands (ASALs) of Kenya are characterised by low erratic rainfall that lead to long and recurring drought periods over the years. This has constrained livestock productivity due to loss of palatable forages. The *Acacia* species (leaves, twigs and pod fruits) together with other forage trees and shrubs are the major source of energy, protein, vitamins and minerals for ruminant livestock during the dry seasons (Bamikole et al., 2003; Osuga et al., 2007). During this period the grasses are of low nutritive value and deficient in nitrogen and digestible nutrients (Ngwa et al., 2001; Rubanza et al., 2005). The crude protein (CP) levels in the pastures fall below optimal levels required for rumen microbial function (Kahindi et al., 2007) and the available energy only meet the animal's maintenance requirement (Sawe et al., 1998). Tree forages and shrubs in the ASALs regenerate very fast during the rainy seasons resulting in heavy vegetative masses while during the lean (dry) period the palatable vegetation especially the grasses deteriorate both in quality (low protein) and quantity (low herbage biomass) (Salem et al., 2006). The browse forages can be harvested, stored and utilized as protein supplement during the dry periods of the year.

Goats selectively feed on a mixture of browse trees and shrubs when allowed to browse freely. This leads to a diverse supply of nutrients as compared to when they are restrained to a single species of forage. The provision of browse mixtures tends to alter the type and number of rumen micro-organisms (Wambui et al., 2012) and extends the choice of available feeds diluting the levels of anti-nutritional factors in the forages while increasing the palatability (Ngwa et al., 2003). During their secondary metabolism, browse plants produce some secondary chemical compounds (phenolics, tannins, terpenoids, amino acid derivatives, alkaloids, saponins), which have storage and defensive functions for the plant's adaptability (Ngwa et al., 2003). However,

the compounds are known to limit the utilization of the forages by ruminants (Kaithoet al., 1998). In the rumen, tannins bind to proteins, carbohydrates, minerals, and other dietary nutrients forming complexes (Makkaret al., 1995; Makkar, 2000) which render the nutrients unavailable and depress their voluntary intake by livestock (Kaitho et al., 1998; Barry and McNabb, 1999).

Acacia browse species have been found to contain high levels of CP (149.5 - 248.6 g/kg DM) (Osuga et al., 2006). This can bridge nutritional gap in low quality pastures and forages. Browse forages maintain their protein content for a considerable time (Dzowela et al., 1995), but the quantities vary with the age and species of the forage, plant parts (leaf, stem, pods), stage of maturity, and presence or absence of secondary compounds (Woodward and Reed, 1989). The fiber component, mainly neutral detergent fiber (NDF), acid detergent fiber (ADF) and acid detergent lignin (ADL) in these browse forages increase with their maturity, with variations between and within species (Reed, 1986). Browse forages with low to moderate fiber content (200 - 235 g/kg DM), positively influence their voluntary intake and digestibility as compared to species with high lignin contents which have low digestibility potential (Norton, 1998). Therefore, the current study was conducted to evaluate the potential nutritive value of browse forage mixtures as well as to assess the palatability of the browse forage mixtures when offered to growing Small East African goats.

II. Materials and Methods

Forage samples

The leaves from five browse forages namely; *Acacia brevispica*, *A. mellifera*, *A. nilotica*, *Zizyphus mucronata* and *Berchemia discolor* were hand harvested and used for the study. The browse forages were selected based on farmers' knowledge of the species consumed by animals in these areas and previous studies in Kenya and other parts of Africa (Abdulrazak et al., 2000; Aganga et al., 2001; Rubanza et al., 2005; Osuga et al., 2008). The forages were harvested at Egerton University's Chemeron Field Station in Marigat, Baringo County, Kenya. The area is at an altitude of 1066 m above sea level. The average annual rainfall and temperature are about 700 mm and 24°C, respectively. The browse forages were harvested from at least 10 trees of each species selected at random within the study area towards the end of the October – December short rains, pooled together, dried under shade and stored in gunny bags away from direct sunlight.

Five browse mixtures were formulated having been selected based on their crude protein (CP) content and *in vitro* dry matter degradability (IVDMD). The mixtures were:

- i) *Z. mucronata* and *A. mellifera* (50:50)
- ii) *Z. mucronata*, *A. brevispica*, *A. mellifera* and *A. nilotica* (25:25:25:25)
- iii) *B. discolor*, *Z. mucronata*, *A. mellifera* and *A. nilotica* (25:25:25:25)
- iv) *B. discolor* and *A. nilotica* (50:50)
- v) *A. mellifera* and *A. nilotica* (50:50)

Chemical analysis

Chemical composition of the browse mixture samples was determined prior to palatability experiment using procedures described by AOAC (1990). Dry matter (DM) was determined by heating the samples in an oven set at 105 °C overnight. The ash content was determined by heating at 550°C overnight in a muffle furnace. The organic matter (OM) was then determined by subtracting ash content from 100. The fat content was determined using diethyl ether as the extractant. Crude protein (CP) was determined using the Kjeldahl method by determining the nitrogen content (%) and multiplying by the factor 6.25. The neutral detergent fibre (NDF), acid detergent fibre (ADF) and acid detergent lignin were analysed using reagents and methods described by Van Soest et al. (1991).

In vitro study

Rumen fluid

The research protocol regarding animal use followed the guidelines recommended in the *Guide for the Care and Use of Agricultural Animals in Agricultural Research and Teaching* (Federation of Animal Science Societies 1999). Rumen liquor for the IVDMD and *in vitro* gas production experiments was obtained from a steer fitted with a permanent rumen fistula. The animal was fed on Rhodes grass (*Chloris gayana*) hay diet, supplemented with concentrates twice daily at 09.00h and 16.00h in equal portions and free access to water and mineral block. The rumen liquor was drawn in the morning at 08.00h, before the animal was fed. The collected rumen liquor/digesta mixture was strained through four layers of cheesecloth and maintained at 39°C according to Menke and Steingass (1988) procedure. The processing of rumen liquor was done under carbon dioxide (CO₂) flushing to maintain anaerobic condition.

***In vitro* dry matter digestibility**

Each browse mixture sample weighing approximately 0.5 g was drawn in triplicate for IVDMD experiment according to Tilley and Terry (1963) method. The samples were incubated at 39°C for 48 hours, after which fermentation was stopped, the tubes were centrifuged, and supernatant fluid discarded. Acidified pepsin was added, and the tube incubated for another 48 hours at 39°C. The content was filtered, and the residue dried and weighed. *In vitro* dry matter disappearance was determined using the formula: -
IVDMD % = $100 \times \frac{[(\text{initial dry sample wt}) - (\text{residue} - \text{blank})]}{(\text{Initial dry sample wt})}$

The blank value was determined by incubating a tube containing rumen liquor and buffer, without any feed sample to determine indigestible materials introduced into the vessel by the rumen fluid inoculums.

***In vitro* gas production**

About 200 mg of sample (milled through a 1.0 mm sieve) were incubated *in vitro* with rumen fluid in calibrated glass syringes following the procedure of Menke and Steingass (1988). The syringes were pre-warmed at 39 °C before addition of 30±1 ml of rumen liquor-buffer mixture (ratio 1:2) into each syringe and incubated in a water bath maintained at 39 °C. Blanks with buffered rumen fluid only were also included. The gas production readings were recorded after 3, 6, 12, 24, 48, 72 and 96 h of incubation. The gas production characteristics were estimated by fitting the mean gas volumes to the exponential equation of Ørskov and McDonald (1979):

$$G = a + b(1 - e^{-ct}),$$

where

- G is the gas production (ml) at time t,
- a is the gas production from the immediately soluble fraction (ml),
- b is the gas production from the insoluble but degradable fraction (ml),
- a + b is the potential gas production (ml),
- c is the rate constant of gas production (fraction/h).

Palatability evaluation

The study was conducted at the Small ruminants unit, Kenyatta University, Main campus, Kenya, altitude of 1564 m above sea level. Five male small East African goats (mean weight 24.0 kg), about 1 year old were used in the study. The animals were housed in a roofed shed, with well-ventilated individual pens of dimensions (1.5 x 1.0 x 1.5M) for the experimental period. Each pen had water and feed trough with five partitions enough for the five test forage mixtures. Clean water and commercial mineral block were available *ad libitum* throughout the experiment. The animals were drenched with an anti-helminth while an acaricide was applied to control ecto-parasites before commencement of the experiment. The animals were allowed to acclimatize to the pens and forages for seven days prior to experimental period of five days as outlined by Rogosic et al. (2006). The browse mixtures were weighed and placed in each partition of the trough at 08:00h, then added as the levels depleted in 30 minutes intervals until 14:00h. The refusals and spillages were collected and weighed. Then chopped (30-40 mm) Rhodes grass (*Chloris gayana*) hay was offered *ad libitum*.

The amounts of browse mixtures offered, and refusal were monitored for calculation of the intake levels. Each day the position of the forage mixture in the feed trough partition was changed. The intake and palatability ranking of the browse forage mixtures were determined from the Coefficient of Preference (CoP) value. This was calculated from the ratio of the intakes of each individual feed sample divided by the average intake of the feed samples (Karbo et al., 1993; Bamikole et al., 2003). Browse mixtures with CoP > 1 were relatively preferred by the goats.

$$\text{CoP} = \frac{\text{Intake of individual feeds offered}}{\text{Mean intake of all the feeds offered}}$$

Statistical analysis

All the data were subjected to analysis of variance using the General Linear Model procedure of the statistical analysis system (SAS) Version 8.1 (SAS Institute, NC, USA). Significance between means was tested using Fisher's least significance difference.

III. Results and Discussion

The chemical composition of the browse forage mixtures is shown in Table 1. The organic matter (OM) content in the browse forage mixtures ranged from 889.9 g/kg DM in *Z. mucronata* & *A. mellifera* forage mixture to 927.4 g/kg DM in *A. mellifera* & *A. nilotica* mixture. The CP content ranged from 153.9 g/kg DM in *B. discolor* & *A. nilotica* forage mixture to 184.4 g/kg DM in *Z. mucronata* & *A. mellifera* forage mixture, while the total fibre content as measured by NDF ranged from 313.7 g/kg DM in *Z. mucronata* & *A. mellifera* forage

mixture to 440.4 g/kg DM in the forage mixture containing *Z. mucronata*, *A. brevispica*, *A. mellifera* & *A. nilotica*. The IVDMD ranged from 57.1% in *B. discolor* & *A. nilotica* to 64.0 % in the browse mixture containing *Z. mucronata*, *A. brevispica*, *A. mellifera* & *A. nilotica*.

Table 1: Chemical composition of the browse forage mixtures (g/kg DM) and *In Vitro* Dry Matter Digestibility (%)

Browse forage mixtures	DM	Ash	OM	CP	NDF	ADF	ADL	IVDMD
<i>B. discolor</i> & <i>A. nilotica</i>	905.1	75.8	924.2	153.9	423.0	198.8	105.9	57.1
<i>Z. mucronata</i> , <i>A. brevispica</i> , <i>A. mellifera</i> & <i>A. nilotica</i>	914.1	88.6	911.4	173.3	440.4	243.6	114.5	64.0
<i>Z. mucronata</i> & <i>A. mellifera</i>	908.3	110.1	889.9	184.4	313.7	201.2	100.1	62.9
<i>A. mellifera</i> & <i>A. nilotica</i>	924.2	72.6	927.4	173.6	367.0	212.2	102.0	61.8
<i>B. discolor</i> , <i>Z. mucronata</i> , <i>A. mellifera</i> & <i>A. nilotica</i>	925.0	84.8	915.2	165.6	386.3	204.3	104.2	63.7

DM, dry matter; OM, organic matter; CP, crude protein; NDF, neutral detergent fiber; ADF, acid detergent fiber; ADL, acid detergent lignin; IVDMD, *in vitro* dry matter digestibility.

The chemical composition of the browse forage mixtures was within the range reported for similar forages from Kenya (Osuga et al., 2008; Wambui et al., 2012; Ndathi et al., 2013; Ondiek et al., 2017) and other areas of the tropics (Mtui et al., 2009). Ondiek et al. (2017) reported similar OM range for forages from the same region. The moderate ash content indicate high mineral content for livestock consuming the forages but also considerable amounts of the other nutrients for livestock upon consumption of the forages. The main contribution of the browse forages to livestock nutrition in the ASAL areas of many parts of the world especially the tropics is the supply of protein (Osuga et al., 2012) which is the most deficient nutrient in most feedstuffs available for feeding livestock in the ASALs and especially during the dry periods. According to Minson (1980) and Leng (1990), low-quality forages are those having less than 80 g/kg DM CP content, this being the critical level below which voluntary intake of tropical forages is limited. The browse forage mixtures evaluated in this study had about 2 fold CP levels above this threshold, and are therefore considered as medium to high quality forages that are able to satisfy the CP requirements of ruminant livestock animals ranging from mature beef cows (70 g/kg DM) (NRC, 1984) to high producing dairy cows (152.0 g/kg DM) (NRC, 2001) to growing goats (100 -150 g/kg DM) (NRC, 2007).

The fibre content of forages as measured by the NDF, ADF and ADL contents is important in describing the nutritive value of forages. This is mainly because NDF is associated with feed intake while ADF and ADL is correlated with digestibility of forages mainly due to the lignified matrix of ADF being the most unavailable feed fraction (Van Soest, 1994). The browse forages mixtures evaluated in this study had low to moderate content of fibre. This would indicate the high nutritive value of the browse forage mixtures especially since the NDF content was below the reported level of 600 g/kg DM (Meissner et al., 1991) beyond which the DM intake by the animals is negatively affected.

Mixing of browse forages does not only increase feeds variety to the animals but also reduces over dependence on one browse species by the animals. The complexes formed lower negative impacts of tannins in the rumen by altering the microbial activities (Rogosis et al., 2008). The high levels of ash in the forage are a crude indicator of total mineral content in the feed, though ash contains materials of organic origin such as sulphur and phosphorus from proteins.

The browse forage mixtures had high IVDMD which has also been reported before for browse forages (Osuga et al., 2006; Osuga et al., 2007). The high digestibility in the browse mixtures shows the extent at which the nutrients are being degraded from the forages and their suitability for use in feeding ruminant animals in the tropics and especially during the dry periods when there is usually feed scarcity and low digestibility in most of the available feedstuffs. Getachew et al. (2000) demonstrated that the browse forages are better used as protein supplements of poor quality roughages such as hay and straws.

The *in vitro* cumulative gas production and the fermentation characteristics of the browse forages are summarized in Table 2. The cumulative gas production varied significantly ($p < 0.05$) over time between the browse forage mixtures. At 24 hours of incubation, the cumulative gas production ranged from 25.3 mL gas/200mg DM in *B. discolor* & *A. nilotica* mixture to 39.3 mL gas/200mg DM in *Z. mucronata*, *A. brevispica*, *A. mellifera* & *A. nilotica* mixture. *B. discolor*, *Z. mucronata*, *A. mellifera* & *A. nilotica* mixture had the highest ($P < 0.05$) potential gas production, while *B. discolor* & *A. nilotica* mixture had the lowest ($P < 0.05$) gas production potential. The rate of gas production was highest in *Z. mucronata*, *A. brevispica*, *A. mellifera* & *A. nilotica* mixture and lowest in *B. discolor* & *A. nilotica* mixture.

Table 2: *In vitro* gas production (ML/200mg DM) parameters of browse forage mixtures

Browse Forage Mixtures	3 h	6h	9h	2h	24h	48h	72h	96h	a+b (mL)	c (%/h)
<i>Z. mucronata</i> & <i>A. mellifera</i>	5.5 ^b	8.3 ^a	12.7 ^b	19.3 ^b	33.6 ^b	38.0 ^c	40.7 ^c	41.8 ^c	50.3 ^c	1.9 ^b
<i>Z. mucronata</i> , <i>A. brevispica</i> , <i>A. mellifera</i> & <i>A. nilotica</i>	6.0 ^a	8.7 ^a	14.8 ^a	24.1 ^a	39.3 ^a	49.2 ^a	51.9 ^a	53.6 ^a	60.8 ^b	2.4 ^a
<i>B. discolor</i> , <i>Z. mucronata</i> , <i>A. mellifera</i> & <i>A. nilotica</i>	4.3 ^c	6.0 ^b	9.8 ^c	15.7 ^c	28.2 ^c	40.1 ^b	42.3 ^b	45.0 ^b	68.8 ^a	1.0 ^c
<i>B. discolor</i> & <i>A. nilotica</i>	3.9 ^c	5.0 ^c	10.5 ^c	14.9 ^d	25.3 ^c	35.2 ^d	36.9 ^d	38.5 ^d	46.4 ^c	0.8 ^d
<i>A. mellifera</i> & <i>A. nilotica</i>	2.7 ^d	4.3 ^c	8.7 ^d	14.7 ^d	26.1 ^d	34.7 ^d	36.9 ^d	39.1 ^d	55.4 ^d	1.2 ^c

Means in the same column with different superscripts differ significantly ($P < 0.05$). a: gas production (ml) from quickly soluble fraction, b: gas production (ml) from insoluble but degradable fraction, c: gas production rate (%/h).

The significant differences ($P < 0.05$) among the browse forage mixtures for their *in vitro* gas production and fermentation characteristics are in agreement with previous studies on similar forages from East Africa especially as single forages (Abdulrazak et al., 2000; Osuga et al., 2006; 2007). Gas production results from fermentation of the feed to short-chain fatty acids (SCFAs) and CO₂ released from the buffering of the produced SCFAs by bicarbonate buffer. Therefore, the differences in gas production among the various species could be due to the amount of substrate fermented and the SCFAs produced upon substrate fermentation. The differences in the rates and extent of the fermentation of the various browse forage mixtures could be related to the differences in their chemical compositions, especially the CP, fibre and tannin composition. For instance, the low extent and rate of gas production in *B. discolor* & *A. nilotica* mixture could be related to the comparatively low CP content and high fibre content of the mixture. In previous studies, *A. nilotica* has also been reported to contain high levels tannins, which also could have contributed to the lower gas production and fermentation characteristics (Osuga et al., 2007).

The mean intake and palatability of the browse forage mixtures is summarized in Table 3 below. There was significant ($P < 0.05$) differences in the intake of the browse forage mixtures by goats. Browse mixture containing *Z. mucronata*, *A. brevispica*, *A. mellifera*, *A. nilotica* and mixture containing *B. discolor*, *Z. mucronata*, *A. mellifera* and *A. nilotica* were the most preferred by the animals and had a CoP of 1.51 and 1.02 respectively. The two browse forage mixtures also had the highest ($p < 0.05$) intakes (168.6 and 113.3 g DMI/6h respectively) by the goats.

Table 3: Intake of browse forage mixtures offered to goats

Browse Forage Mixture	Mean (g DMI/ 6h)	CoP
<i>A. mellifera</i> & <i>A. nilotica</i>	92.2 ^c	0.83
<i>B. discolor</i> & <i>A. nilotica</i>	87.9 ^c	0.79
<i>Z. mucronata</i> & <i>A. mellifera</i>	95.0 ^c	0.85
<i>Z. mucronata</i> , <i>A. brevispica</i> , <i>A. mellifera</i> & <i>A. nilotica</i>	168.6 ^a	1.51
<i>B. discolor</i> , <i>Z. mucronata</i> , <i>A. mellifera</i> & <i>A. nilotica</i>	113.3 ^b	1.02

Means with different superscript in a column differ significantly ($P < 0.05$); CoP, Coefficient of preference

Dry matter intake of the browse forage mixtures was used as an indicator of palatability of the forage mixtures since they were offered to the animals in a cafeteria approach. The intake of forage is however usually influenced by both animal and plant factors. For forages, the intake is influenced by plant species, form of presentation, stage of maturity, methods of processing and chemical constituents of the fodder (Kalio et al., 2006). The level of occurrence of anti-nutritional factors such as tannins may also affect the palatability of forages and hence preference by the animals. Taste, smell or feel may also play an important role in determination of the palatability of forages (Ngwa et al., 2003). The high palatability observed in *Z. mucronata*, *A. brevispica*, *A. mellifera* and *A. nilotica* browse mixture is in agreement with the gas production potential of the mixture, which was high as well as the high OM and CP (911.4 and 173.3 g/kg DM respectively) of the mixture.

Marten (1978) reported that the relative palatability of any feed depends on the nature of the associative effect with the feeds on offer. This may explain the high palatability of browse mixtures with many species of browse forage involved. The mixing of many browse forage may also help to dilute the any negative effect of anti-nutritional compounds such as tannins that may be present in some of the browse forages. In previous studies (Abdulrazak et al., 2000; Osuga et al., 2008) browse species such as *A. nilotica* and *A. brevispica* have been reported to contain tannins. It is therefore possible that the effect of tannins present in such species of browse could have been masked by the ingestion of the other feeds. The activity of the tannins present in the some of these browse species may not be as biologically active as in other species.

However, it has been noted before that the differences in preference by animals may alter depending on the adaptation of animals to variations of forage nutritional levels through the year (Osuga et al., 2006). This is

because some browse species that are least preferred during periods when fodder availability is high could be relished during periods when available and affordable feeds are scarce, based on animal survival instinct. Therefore, having a variety of browse species in farming systems will ensure year-round availability of fodder for increased animal productivity.

IV. Conclusion

On the basis of chemical composition (high CP and low fibre content) and *in vitro* gas production, the browse forage mixtures have nutritive potential as supplements to low-quality feeds, especially during the dry season. The use of many browse forages as mixtures when feeding the animals tend to improve the palatability of the browse forages and hence improve intake of the forages.

Acknowledgment

Financial aid to the first author (Dr. Isaac Osuga) through a Post-Doc grant by the National Commission for Science, Technology and Innovation, Kenya is highly acknowledged.

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