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

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Abstract
In this study the chemical composition, in vitro drymatter digestibility (IVDMD) and palatabilityof five browse forage mixtures were studied. The five forage mixtures were selected based ontheir nutritive value and IVDMD and from reported previous studies of single species.The species included Acacia brevispica, Acacia mellifera, Acacia nilotica, Zizyphusmucronata and Berchemia discolor. In vitro gas production technique was used to determine the rumen fermentation characteristics. Palatabilityof the browse forage mixtures was determined based on the mixture's voluntary intakebya cafeteria approach on growing small East African goats. The crude protein (CP) content ranged from 153.9 g/kg dry matter (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 indicates that browse foragemixtures are highly palatable andhave great potential as supplements for poor-quality basal dietsin the marginal areas of the tropicsand can enhance performance of livestock especially the small ruminants.

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

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I. Introduction

The arid and semi-arid lands (ASALs) of Kenya are characterised by low erratic rainfall that lead to long and recurring drought periodsover the years. This hasconstrained livestock productivity due to loss of palatable forages. The *Acacia* species (leaves, twigsand pod fruits) together with other forage trees and shrubs are the major source of energy, protein, vitamins and minerals forruminant livestock during the dry seasons (Bamikole et al., 2003; Osuga et al., 2007).During this period the grasses areof low nutritive value and deficient in nitrogen and digestible nutrients (Ngwa et al., 2001; Rubanza et al., 2005). Thecrude protein (CP) levels in the pastures fall below optimal levels required for rumen microbial function (Kahindi et al., 2007) and the available energy only meetthe 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 (Wambuiet al., 2012) and extends the choice of available feeds diluting the levels of anti-nutritional factors in the forageswhile 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 tolimit 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 intakeby 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 (Dzowelaet 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 the assess the palatability of the browse forage mixtures when offered to growing Small East African goats.

II. Materials and Methods

Foragesamples

The leaves from five browse foragesnamely; *Acaciabrevispica, A.mellifera, A.nilotica, Zizyphusmucronata*and*Berchemiadiscolor*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 (Abdulrazaket al., 2000; Agangaet al., 2001; Rubanzaet 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 altitude of 1066 m above sea level. The average annual rainfall and temperature are about 700 mm and 24^{o}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 mixturesamples 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 ^{0}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 Soestet 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 ofAgricultural 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 portionsand 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 cheesecloth and maintained at 39^{o}C according to Menke and Steingass (1988) procedure. The processing of rumen liquor was done under carbon dioxide (CO_2) flushing to maintain anaerobic condition.

***In vitro*dry matter digestibility**

Each browse mixture sample weighing approximately 0.5g was drawn in triplicate for IVDMD experiment according to Tilley and Terry (1963) method. The samples were incubated at 39^{o}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^{o}C. The content was filtered, and the residue dried and weighed. *In vitro* dry matter disappearance was determined using theformula: -

$$\text{IVDMD \%} = 100 \times \frac{[(\text{initial dry sample weight}) - (\text{residue} - \text{blank})]}{(\text{Initial dry sample weight})}$$

The blank value was determined by incubating a tube containing rumenliquor 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 ^{o}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 ^{o}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):

$$G = a + b(1 - e^{-c\,t}),$$

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 availed *ad libitum* throughout the experiment. The animals were drenched with an anti-helminth while an acaricidewas 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 Rogosicet 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.Thenchopped (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 thebrowse forage mixturesis 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
B. discolor & A. nilotica	905.1	75.8	924.2	153.9	423.0	198.8	105.9	57.1
Z. mucronata, A. brevispica, A. mellifera& A. nilotica	914.1	88.6	911.4	173.3	440.4	243.6	114.5	64.0
Z. mucronata& A. mellifera	908.3	110.1	889.9	184.4	313.7	201.2	100.1	62.9
A. mellifera& A. nilotica	924.2	72.6	927.4	173.6	367.0	212.2	102.0	61.8
B. discolor, Z. mucronata, A. mellifera& A. nilotica	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.Thebrowse 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 animalsbut 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 (Rogosic et al., 2008).The high levels of ash in the forage are a crude indicator of total mineral content in the feed,though ashcontains 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)
Z. mucronata& A. mellifera	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}
Z. mucronata, A. brevispica, A. mellifera& A. nilotica	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}
B. discolor, Z. mucronata, A. mellifera& A. nilotica	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}
B. discolor & A. nilotica	3.9^{c}	5.0^{c}	10.5^{c}	14.9^{d}	25.3^{e}	35.2^{d}	36.9^{d}	38.5^{d}	46.4^{e}	0.8^{d}
A. mellifera& A. nilotica	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 CO_2 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& 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
A. mellifera& A. nilotica	92.2^{c}	0.83
B. discolor & A. nilotica	87.9^{c}	0.79
Z. mucronata& A. mellifera	95.0^{c}	0.85
Z. mucronata, A. brevispica, A. mellifera& A. nilotica	168.6^{a}	1.51
B. discolor, Z. mucronata, A. mellifera& A. nilotica	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& 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.

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References

[1]. Abdulrazak S A, Fujihara T, Ondiek J O and Ørskov E R 2000: Nutritive evaluation of some acacia from Kenya. Journal of Animal Feed Science and Technology 85: 89-98.
[2]. Aganga A A, Ompole U J and Balegeng L 2001: Performance of Tswana goats fed *Acacia Mellifera, Euclea Undulate* and *PeltophorumAfricanum* as Supplements to Buffel Grass. Arch Zootec 50: 383-386.
[3]. AOAC 1990: Official Methods of the Association of Analytical Chemists 15th Ed Vol, I, Arlington, Virginia, U.S.A
[4]. Bamikole M A, Babayemi O J, Arigbede O M and Ikhatua U J 2003 Nutritive value of *Ficusreligiosa* in West Africa Dwarf goats.Journal of Animal Feed Science and Technology 105: 71-79.
[5]. Barry T N and McNabb W C 1999 The implications of condensed tannins on the nutritive value of temperate forages fed to ruminants. British Journal of Nutrition 81: 263–272
[6]. Dzowela B H, Hove L, Topps J H and Mafongaya P L 1995: Nutritional and anti-nutritional characters and rumen degradability of dry matter and nitrogen for some multipurpose tree species with potential for agro-forestry in Zimbabwe. Animal Feed Science and Technology 55:207-214.
[7]. Getachew G, Makkar H P S and Becker K 2000: Effect of polyethylene glycol on in vitro degradability of nitrogen and microbial protein synthesis from tannin rich browse and herbaceous legumes. British Journal of Nutrition 84: 73 – 83.
[8]. Kahindi R K, Abdulrazak S A and Muinga R W 2007 Effect of supplementing Napier grass (*Pennisetum purpureum*) with Madras thorn (*Pithecellobiumdulce*) on intake, digestibility and live weight gains of growing goats. Small Ruminant Research 69:83–87.
[9]. Kaitho R J, Nsahlai I V, Williams B A, Umunna N N, Tamminga S and Van Bruchem J 1998 Relationships between preference, rumen degradability, gas production and chemical composition of browses. Agroforestry Systems 39:129–144
[10]. Kalio G A, Oji U I and Larbi A 2006: Preference and palatability of indigenous and exotic acid soil-tolerant multipurpose trees and shrubs by West African Dwarf sheep. Agroforestry Systems 67: 123 –128
[11]. Karbo N, Barnes P and Rudat H 1993: An evaluation of browse forage preferences by sheep and goats in the Northern Guinea Savannah zone, Ghana. In: Ndikumana J. and de Leeuw p. Eds., Sustainable Feed Production and Utilization of Smallholder Livestock Enterprises in Sub-Saharan Africa. Proceedings of the Second African Feed Resources Network (AFRNET), Harare, Zimbabwe, pp. 107 – 110
[12]. Leng R A 1990: Factors affecting the utilization of 'poor quality' forages by ruminants particularly under tropical conditions. Nutrition Research Reviews 3: 277 – 303
[13]. Makkar H P S and Singh B 1995 Determination of condensed tannins in complexes with fiber and proteins. Journal of Science Food Agriculture 69:129-132.
[14]. Makkar, H.P.S 2000: Quantification of tannins in tree forage, a laboratory manual for the FAO/ IAEA Co-ordinated research project on 'use of nuclear and related techniques to develop simple tannin assays for predicting and improving the safety and efficiency of feeding ruminants on tanniniferous tree forage'. Joint FAO/ IAEA of Nuclear Techniques in Food and Agriculture, *Animal Production and Health Sub-programme, FAO/ IAEA Working Document, IAEA Vienna, Austria, 2000.*
[15]. Meissner H H, Koster H H, Nieuwoudt S H and Coetze R J 1991: Effects of energy supplementation on intake and digestion of early and mid-season ryegrass and Panicum/Smuts finger hay, and on in sacco disappearance of various forage species. South African Journal of Animal Science 21: 33 – 42
[16]. Menke KH and Steingass H 1988: Estimation of the energetic feed value obtained from chemical analysis and *In vitro* gas production using rumen fluid. Animal Research and Development 28:7-55.
[17]. Minson D J 1980: Nutritional differences between tropical and temperate pastures. In: Morley F. H. W. (ed.), Grazing Animals. CAB, Furnham Royal, Slough UK, pp. 167-182.
[18]. Mtui D J, Lekule F P, Shem M N, Ichinohe T and Fujihara T 2009: Comparative potential nutritive value of grasses, creeping legumes and multipurpose trees commonly in sub humid region in the Eastern parts of Tanzania. Livestock Research for Rural Development. Volume 21, Article #158. Retrieved August 6, 2018, from http://www.lrrd.org/lrrd21/10/mtui21158.htm
[19]. Ndathi A J N, Muthiani E N, Ndung'u J N, Ogillo B P, Kimitei R K, Manyeki J K, Katiku P N and Mnene W N 2013: Feed resources and utilization strategies in selected pastoral and agropastoral communities in Kenya. Livestock Research for Rural Development. Volume 25, Article #221. Retrieved August 6, 2018, from http://www.lrrd.org/lrrd25/12/ndat25221.htm
[20]. Ngwa A T, Nsahlai I V and Bonsi M L 2003 Feed intake and dietary preferences of sheep and goats offered hay and legume-tree pods in South Africa. Agroforestry Systems 57:29-37 http://dx.doi.org/10.1023/A:1022988200484
[21]. Norton B W 1998: The nutritive value of tree legumes, in: gutteridge, R.C and Shelton, H.M (Edts), Forage Tree Legumes in Tropical Agriculture. Tropical Grassland Society of Australia Inc, P. 177-191.
[22]. NRC 1984: Nutrient requirements of beef cattle. 6th revised edn., National Academy Press, Washington, DC.
[23]. NRC 2001: Nutrient requirements of dairy cattle. 7th revised edition. National Academy of Sciences, Washington, DC, USA.
[24]. NRC 2007: Nutrient Requirements of Small Ruminants. Sheep, Goats, Cervids, and New World Camelids. National Academy Press, Washington, DC.
[25]. Ondiek J O, Abdulrazak S A and Njoka E N 2017: Nutritive value and palatability rating of fifteen selected indigenous Kenyan browse species fed to Small East African goats. Livestock Research for Rural Development. Volume 29, Article #115. Retrieved August 6, 2018, from http://www.lrrd.org/lrrd29/6/ondi29115.html

[26]. Ørskov E R and McDonald I 1979: The estimation of protein degradation in the rumen from incubation measurements weighted according to the rate of passage. Journal of Agriculture Science Cambridge 92:499-503.
[27]. Osuga I M, Abdulrazak S A, Muleke C I and Fujihara T 2012: Effect of supplementing Rhodes grass Hay (*Chloris Gayana*) with *Berchemia Discolor* or *ZizyphusMucronata*on the performance of growing goats in Kenya. Journal of Animal Physiology and Nutrition 96:634-639.
[28]. Osuga I M, Abdulrazak S A, Nishino N, Ichinohe T and Fujihara T 2006: Potential nutritive value of selected browse species from Kenya using in vitro gas production technique and polyethylene glycol. Livestock Research for Rural Development. Volume 18, Article #171. Retrieved July 6, 2018, from http://www.lrrd.org/lrrd18/12/osug18171.htm
[29]. Osuga I M, Maindi C N, Abdulrazak S A, Nishino N, Ichinohe T and Fujihara T. 2007: Potential nutritive value and tannin bioassay of selected acacia species from Kenya. Journal of the Science of Food and Agriculture.87: 1533-1538.
[30]. Osuga I M, Wambui C C, Abdulrazak S A, Ichinohe T and Fujihara T 2008: Evaluation of nutritive value and palatability by goats and sheep of selected browse forages from semi arid area of Kenya. Animal Science Journal 79:582–589.
[31]. Reed, J.D. 1986: Relationship among soluble phenolics, insoluble proanthocyanidins and fiber in East African browse species. *Journal of Range Management, 39 (1),* 5-7.
[32]. Rogosic J, Pfister J A, Provenza F D and Grbesa D 2006: Sheep and goat preference for and nutritional value of Mediterranean Maquis shrubs. Small Ruminant Research 64:169–179.
[33]. Rogosic J, Pfister J A, Provenza F D and Pavlicevic J 2008:The Effect of Polyethylene Glycol on Intake of Mediterranean Shrubs by Sheep and Goats. Journal of Animal Science 86:3491–3496.
[34]. Rubanza C D K, Shem M N, Otsyana E R, Bakengesa S S, Ichinohe T and Fujihara T 2005 Polyphenolics and tannins effect on *in vitro* digestibility of selected *Acacia* species leaves. Animal Feed Science Technology. *119*:129-142.
[35]. Salem A Z M, Salem M Z M, El-Adawy M M and Robinson P H 2006 Nutritive evaluations of some browse tree foliages during the dry season: secondary compounds, feed intake and in vivo digestibility in sheep and goats, Journal of Animal Feed Science and Technology 127:251-267
[36]. Sawe J J, Tuitoek J K and Ottaro J M 1998 Evaluation of common tree leaves or pods as supplements for goats on range area of Kenya. Small Ruminant Research 28:31–37
[37]. Tilley J M A and Terry R A 1963: A two stage technique for the *in vitro* digestion of forage crops. Journal of British Grassland Society, 18:104-111.
[38]. Van Soest P J 1994: *Nutritional Ecology of the Ruminants,* Cornell University Press, Ithaca and London, Pp 476
[39]. Van Soest P J, Robertson J B and Lewis B A 1991: Methods of fiber, neutral detergent fiber and non- starch carbohydrates in relation to animal nutrition. Journal Dairy Science, 74.3583–3597.
[40]. Wambui C C, Ando S, Abdulrazak S A, Osuga I M and Ichinohe T 2012 *In vitro* assessment of ruminal fermentation characteristics of tropical browse mixtures supplemented with yeast. Grassland Science58:53–57
[41]. Woodward A and Reed J D 1989: The influence of polyphenolics on the nutritive value of browse. A summary of research conducted at ILCA. ILCA Bull 34: 2 – 11

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