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Forage Quality and Methane Reduction Potentials of Selected Browse Species from Borana Rangeland, Southern Ethiopia

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Abstract: The study was conducted to assess leaf biomass production, chemical composition, *in vitro* gas and methane production, rumen degradation and tannin biological activities of selected browse species from Borana rangeland of Southern Ethiopia. Twenty three browse species namely, *Acacia brevisca, Acacia busei, Acacia drapanolobium, Acacia melifera, Acacia nilotica, Acacia nubica, Acacia , Senegal, Acacia seyal, Acacia toritlis, Acacia oerfota, Angeosis leiocarpa, Asparagus spp, Balanites aegyptica, Boswella neglecta, Cadaba farinose, Carrissa spinarum, Commiphora Africana, Croton macrostachys, Grewia bicolor, Justica odora, Rhus natelensis, Terminalia browini and Ziziphus spina-Christi* were selected for this study as they were identified as main browse species for dry season supplementation. Plant density, leaf biomass yield (DMY) and leaf protein yield (CPY), as well as chemical and nutritional composition of the leaf biomass such as y dry matter (DM), ash, crude protein (CP), neutral detergent fiber (NDF), acid detergent fiber (ADF), acid detergent lignin (ADL), total phenolics (TP), total tannins (TT), condensed tannin (CT) were determined for the browse species. Plant density from 1343-69 plant/ha and from 39.8-5.6 kg/plant, DMY 1803-391 kg/ha, CPY 267.1-43.5 kg/ha, DM 96.8-89.6% DM, ash 15.7- 6.8 % DM, CP 28.7-13.8 % DM, NDF 43.2-25.4 % DM, ADF 20.3-11% DM, ADL 14.2- 6.0% DM, TP 31.4-19.1 % DM, TT 27.5-11.7 % DM, CT19.4-3.2 % DM, Ca 2.15-1.43 % DM and P0.42-0.22 % DM of the leaf biomass. Gas volume after 24 hrs of incubation ranged from 29.4-51.2 ml /200 mg DM while at 48 hrs of it ranged from 39.0- 56.6 ml/ 200 mg DM. The gas production from the soluble fraction (a) ranged from 13.8-24.3 % DM, gas production from the insoluble but rumen degradable portion (b) 50.0-78.5 % DM, rate of gas production (c) 0.012-0.043 /h and potential gas production (a+b) 67.0-93.7 % DM. Organic matter digestibility (OMD) ranged from 42.2-58.0 % DM, short chain fatty acids (SCFA) 0.33 to 2.01 mmol/liter, metabolisable energy (ME) production 7.2-10.4 MJ/kg , methane production 9.1-15 ml/200mg DM, methane reduction potential (MRP) 12.2-57.5 and Partitioning factor (PF) 1.47-2.36 in the leaf biomass. Tannin bioassay by addition of polyethylene glycol (PEG) was observed to change gas production, OMD, ME and SCFA production from treated leaves while PEG had no effect on the above parameters for blank syringes. Increase in gas production on 24 hrs of incubation ranged from 6.2-70.4%, at 48 hrs of incubation 7.9-72.5%, methane production 3.3-24.8 % , SCFA production 6.1-166% and ME production 1.1-76.6% .The *in sacco* degradability of the DM of the browse species was also evaluated. The instantly soluble fraction (A) ranged from 19.2-30 DM while degradability of the insoluble but degradable fraction (B) 41.4- 64.2 % DM, Potential degradability (A+B) 64.2- 85.3 % DM and effective degradability (ED) 33.2- 63.4 % DM in the browse species. *In sacco* degradability experiment ranked the browse species in the following decreasing order: *Croton macrostachys>Rhus natelensis>Boswella comiphora>Acacia drapanolobium>Acacia busei>Ziziphus spina –Christi>Terminelia browini>Angeosis leiocarpa>Justica odora>Acacia toritilis>Asparagus spp>Carrisa spanara>Commiphora Africana.* The evaluated browse species had medium to high nutritional values and phenolic composition, gas production and tannin biological activities, low to medium methane production and higher DM disappreance values. The authors recommended further evaluation of these browse species to reduce the CT level of the feeds to threshold level as well as animal feeding experiments for effective utilization of these feed resources as dry season supplementation to grazing ruminants.

Key words: In sacco degradability · *In vitro* gas production · Leaf biomass yield · Methane production · Tannin biological activity

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INTRODUCTION

The Ethiopian lowlands are situated below 1500 m asl and comprise about 61% of the national land area which is about 769 000 km^2. The area experience high temperature as well as erratic and unpredictable annual precipitation, usually less than 700 mm [1]. Moisture stress and extreme rainfall variation between locations and years make animal production the only viable farming system [2]. The semi-arid rangelands support livestock that are valuable as sources of food and cash income for the pastoral and agro-pastoral population, as source of foreign currency for the nation and for provision of draught power for smallholders in the highlands [3]. The livestock population of Ethiopian rangelands was estimated to be about 40% of the cattle, 75% of the goats, 25% of the sheep, 20% of the equines and 100% of the camels of the total livestock population of the country [4]. However their productivity is hampered by critical shortage of livestock feeds in the low lands of the country particularly during dry season. It is well documented that animals consuming basal diets containing less than 7% crude protein (CP) require supplementation for improved performance [5, 6], hence there is need to exploit rangeland browse species for their potential in dry season supplementation.

Browse species play significant role in providing fodder for ruminants in many parts of the World. Most browse species have the advantage of maintaining better nutritive value throughout the dry season than grasses which dry up and deteriorate both in quality and quantity [7]. Browse trees and shrubs are generally richer in protein and minerals [8, 9]. They may be considered as a more reliable feed resource of high quality to develop sustainable feeding systems and in increasing livestock productivity [10]. According to Angassa [11] 83% of the Borana rangelands have been threatened by a combination of bush encroachment and invasion by unpalatable forbs, while only 17% of the rangelands were free from either bush encroachment or invasion by unpalatable forbs. This situation has negative impact on herbaceous growth and biomass production. Therefore, browse species are important feed resources to bridge the gap of feed shortages in rangelands during dry season [12]. Major browse species were documented in Borana rangelands [13, 9 and 14] but information on the potential biomass feed production, chemical composition and nutritional values for browsing livestock are limited. Therefore, it is important to assess browse tree and shrub species using simple techniques like proximate analysis, nylon bag and *in-vitro* gas production methods for their nutritional quality.

Thus, there is a pressing need to evaluate the potential feed values of the indigenous browse trees and shrubs so that they could be used in developing sustainable feeding regimes. This study was, thus, designed with the following objectives: (1) to assess leaf biomass production of main browse species in Borana rangelands (2) to study chemical composition, *in vitro* dry matter digestibility, *in vitro* gas and methane production from selected browse species and (3) to evaluate *in sacco* degradability characteristics and tannin biological activities of main browse species from Borana rangelands

MATERIALS AND METHODS

Study Areas: The Borana area located at 4-6° N and 36-42°E sloping gently from 1600masl in the North-East to about 1000 masl in the extreme South that borders Northern Kenya and about 1780masl in the central vicinity. Borana rangelands occupied almost entirely by pastoral populations. Rangeland uses largely communal, though with crop cultivation and private enclosures that appear to be increasing in recent decades. Rainfall delivery is bimodal; with the long rains accounting for 60% of the total rainfall falling between March and May and the short rains comprising of 27% of the total rainfall falling between September and November. There is spatial and temporal variability in both the quantity and distribution of rainfall with an average annual rainfall varying from 353mm to about 900mm per annum [3].

Sampling Design and Data Collection: A reconnaissance survey of the study areas were made before the actual sample collection in order to obtain information on vegetation stands along the altitudinal gradients in the study areas. A total of 23 browse and shrub species were selected after an initial field survey to evaluate the utilization of multipurpose tree and shrub forage species in two districts of Borana range lands as livestock and wild animals feeds by selected pastoralists, key informants and forage and range experts in the local communities. Three peasant association each in two districts were selected during the field survey and four transect lines were randomly laid in each peasant associations. Along the transect lines five sampling pilots of 20x20 m area at 200m interval along the line or at 50 meters altitudinal drops when there is a steep slope were arranged for sampling of the selected browse and shrub species by the community for livestock feeding. Thus, a total of 120 sampling pilots were used for measurements of biomass yield parameters and collections of browse samples for laboratory analysis.

Identification of the browse species were conducted by knowledgeable pastoralists, key informants and forage and range experts in the local communities by their vernacular names. Their scientific names were consulted from the published volumes of Flora of Ethiopia and Eritrea [15] and technical bulletin of ESGPIP [16]. Browse specimens were properly dried, labeled and transported to National herbarium of Addis Ababa University, Ethiopia for confirmation of their proper identifications.

Determination of Biomass Yield from Trees and Shrubs: In each plots selected browse and shrubs species were counted for determination of density and frequency of occurrence in plots. In addition, for prediction of the biomass yield, the trunk diameters of the plants were measured at 30 cm height for shrubs and 120 cm height for trees using measuring tape and leaf yield per annum were determined using the allometeric equation of $\log w = 2.24 \log dt - 1.5$ [17] to calculate potential biomass yield. The diameters of the plants were obtained by measuring the circumference of the trunk as D=0.318C.Where, C= trunk circumference and D = diameter of the trees.

Sample Collection and Preparation: The browse and shrubs were harvested from at least 10 plants per each species selected at random in the selected peasant associations of two districts both in dry and wet seasons. The harvested samples were pooled for each individual browse and shrubs species and then oven dried at 105°C for 24 h to constant weight. The leaves were then milled through a 2.0 mm screen for *in Sacco* digestibility and a sub sample were taken and milled further through 1.0 mm screen for use in gas production trial and proximate analysis

Chemical Composition: The dry matter (DM), ash, ether extract (EE) and Kjeldahl nitrogen analyses were performed in duplicate on dried samples [18] and CP was calculated as N x 6.25. Neutral detergent fiber (NDF) was determined by the method of Van Soest *et al.* [19] where as acid detergent fiber (ADF) and acid detergent lignin (ADL) were determined according to Van Soest and Robertson [20] using Ankom^{220} fiber analyzer (Ankom Technology®, Macedon, NY, USA). NDF was determined without alpha amylase). Phenolics were extracted using 70% aqueous acetone and total extractable phenolics (TP) determined using Folin Ciocalteu procedures described by Makkar [21]. The TP concentration was calculated using the regression equation of tannic acid standard. Total extractable tannins (TT) was estimated indirectly after being absorbed to insoluble polyvinyl pyrrolidone (PVP) and the concentration calculated by subtracting the TP remaining after PVP treatment. Condensed tannins were determined by using Butanol-HCl procedures and were expressed as leucocyanidin equivalent (% of DM). The concentrations of condensed tannins were calculated by the formula:

$$\frac{\text{Absorbance at 550 nm} \times 78.26 \times \text{Dilution factor}}{\text{\% DM}}$$

The dilution factor was equal to 1 if no 70% acetone was added or 0.5 ml per volume of the extract was taken [22, 23]. Calcium was determined by atomic absorption spectrophotometer and phosphorous was determined by spectrophotometer.

***In sacco* Degradability:** *In sacco* feed evaluation was conducted by using three steers with rumen cannula at nutrition laboratory of Holeta Agricultural research Center, Ethiopia. Duplicate nylon bags (bag size, 80mmx140mm; pore size 45μm) containing 5g of milled dry sample was weighed and then incubated in the rumen of three fistulated steers. The bags were then withdrawn after 3, 6, 12, 24, 48, 72 and 96 hours. The zero hour was obtained by soaking the bags in a water bath maintained at 39°C for 1 hour. After the incubation period, the bags were withdrawn then hand washed under running tap water until the water coming out of the bags was clear. The washed bags and contents were then dried for 48 hours at 60°C in a hot oven to determine DM disappearance. The disappearance values were fitted in the equation of [24]: $Y=A+B(1-e^{-ct})$ where A, B and C are degradation constants.

***In-vitro* Gas Production:** The *in vitro* gas production was carried out at the laboratory of School of animal and range Sciences, Hawassa University, Ethiopia. The gas production technique of Menke and Steingass [25] was used in the *in-vitro* gas production assessment. Rumen fluid was obtained from three male adult Adilo sheep through suction tube before the morning feed. The animals were fed with 40% concentrate feed (wheat bran (40%), maize grain (32%) and linseed cake (27%) and common salt (1%)) and 60% Rhodes grass. Incubation was carried out according to [24] in 120ml calibrated syringes in three batches at 39°C. To 200mg sample in the syringe was added 30ml inoculum that contained cheese cloth strained rumen liquor and buffer (9.8g $NaHCO_3$ + 2.77g Na_2 HPO_4 + 0.57g Kcl + 0.47g NaCl + 0.12g $MgSO_4.7H_20$ + 0.16g $CaCI_2$. $2H_20$ in a ratio (1:4 v/v) under continuous flushing with CO_2. Three incubation runs were conducted for each sample within each shrub species with three replications per sample. The gas production was measured at 3, 6, 12, 24, 48, 72 and 96h. The average volume of gas produced from the blanks was deducted from the volume of gas produced per sample. The volume of gas production characteristics were estimated using the equation $Y = a + b\ (1 - e^{ct})$ [26], where Y = volume of gas produced at time't', a = intercept (gas produced from the soluble fraction), b = gas production from the insoluble fraction, (a+b) = total gas production, c = gas production rate constant for the insoluble fraction (b) and t = incubation time The post incubation parameters such as metabolisable energy (ME, MJ/Kg DM), organic matter digestibility (OMD %) and short chain fatty acids (SCFA) were estimated at 24h post gas collection [26]. At the end of 24 h incubation, 4ml of 1N Na $(OH)_2$ was added to the substrate in each syringe to determine the methane production [27].

In vitro organic matter digestibility (OMD) was calculated from the equation: *OMD (%) = 18.53 + 0. 9239 gas production (at 48 hrs) + 0.0540 CP* [25]. Where: OMD= organic matter digestibility at 48 hours and CP=crude protein (%DM). Metabolisable energy (ME) was calculated from equation: *ME (KJ/gDM) =2.20+0.136GP+0.0057CP* [25] *Where: GP=Gas production over 24rs of incubation; CP=Crude protein content of feed samples,* short chain fatty acids (SCFA) was calculated from equation: SCFA = 0.0239*GP – 0.0601.

Partitioning Factor (PF): In a separate run of gas production completed on samples, the method of Blummel *et al.* [28] was adopted to determine the partitioning Factor (PF). In this method, approximately 300 mg of dried and ground (2mm) browse samples were weighted and placed into serum bottles. Buffered rumen fluid with McDougal buffer (20ml) was pipetted into each serum bottle to measure gas production to 24 h. After termination of incubation, bottles contents were transferred to tubes and centrifuged at 2500´g for 10 min. Supernatants were picked out and solid parts were washed with buffer ($NaHPO_3$, $KHPO_3$, NaCl and distilled water) and centrifuged at 2500×g for 10 min. Then the solid parts were dried in the oven and weighed. The ratio of DM truly degraded (mg) to gas volume at 24 h incubation was used as the partitioning factor Blummel *et al*. [28].

Polyethylenglycol (PEG) Bio-Assay for the Assessment of Tannins: The gas production technique described above was also used for this biological assay. Incubations were carried out in serum bottles with or without the addition of 500 mg PEG. Ground samples (300 mg) were weighed out into serum bottles, kept at approximately 39°C and flushed with CO_2 before use. Two bottles were used for each substrate with each inoculum source (rumen fluid from three sheep was used separately as three different inocula giving three replicates per treatment), one for each treatment (with or without PEG). Bottles were tightly closed and placed in the shaking water bath at 39°C, being shaken at regular times. The volume of gas produced in each bottle was recorded at 6, 12, 24 and 48 h after inoculation time. Gas production was corrected by subtracting the volume of gas produced from blank cultures. Tannin activity was calculated as the ratio between cumulative gas measured in the PEG bottle and that recorded in the control (no PEG) bottle, for each sample and inoculum. For each sample, values from the three replicates (inoculum sources) were averaged.

Statistical Analysis: Analysis of variance was carried out on nutrient and phenolic composition, IVOMD, ME values, SCFA production, methane production and *in sacco* degradability using GLM procedures of [29]. Significance between means was tested using the least significant difference (LSD).

RESULTS

Potential Leaf Biomass and Protein Yields of Selected Browse Species from Two Districts of Borana Rangeland: In a survey conducted in the three peasant associations of Dirre district (*Dambala wachu*, *Dubulluk* and *Mandhacho*) and Teltale district (*Dibe gaya*, *Saba* and *Elkune*) of Borana range lands 23 major indigenous browse species were indentified from 120 households as being used as animal feed resources by the community. The most preferred indigenous browse species with their scientific and vernacular names and potential biomass and protein yields of these browse species are also presented in Table 1 and Table 2 respectively. Plant density (plant/ha) ranged from *Acacia drapanolobium* (643 plant/ha) to *Acacia melifera* (49 plant/ha) in Teltale district and from *Acacia busei* (980 plant /ha) to *Acacia senegal* (69 plant/ha) in Dirre district while Dry matter yield (kg/plant) was the highest in *Ziziphus spina-Christi* (39.8 kg/plant) and the lowest in *Acacia melifera* (5.6 kg/plant) in Teltale district while in Dirre district, the highest was in *Acacia nubica* (55 kg/plant) and the lowest was in *Acacia Senegal* (7.9 kg/ha).

Table 1: Scientific and vernacular names of common browse species selected by local communities in Borana rangeland

Scientific name	Vernacular name	Edible parts
Acacia brevisca	Hammarreessa	Leaf/fruits
Acacia busei	Halloo	Leaf/fruits
Acacia drapanolobium	Fulleessa	Leaf/fruits
Acacia melifera	Saphansa	Leaf/fruits
Acacia nilotica	Burquqqee	Leaf/fruits
Acacia nubica	Waangaha	Leaf/fruits
Acacia senegal	Hidhaadhoo	Leaf/fruits
Acacia seyal	Waaccuu	Leaf/fruits
Acacia toritlis	Dhaddacha	Leaf/fruits
Acacia oerfota	Waangaa	Leaf/fruits
Angeosis leiocarpa	NA	leaf
Asparagus spp	Sareti	leaf
Balanites aegyptica	Baddana	Leaf/fruits
Boswella neglecta	Dakkara	Leaf
Cadaba farinose	Kelkelcha	Leaf
Carrissa spinarum	Agamsa	Leaf/fruits
Commiphora Africana	Hammeessa dhiiroo	Leaf
Croton macrostachys	Makanissa	Leaf
Grewia bicolor	Arroressa	Leaf
Justica odora	NA	Leaf
Rhus natelensis	Debobessa	Leaf
Terminalia browini	Birreessa	Leaf
Ziziphus spina-christi	Kurkura	Leaf

Dry matter yield (kg/ha) ranged from *Acacia drapanolobium* (1126 kg/ha) to *Acacia nubica* (225 kg/ha) but in Dirre district it ranged from *Acacia nubica* (1803 kg/ha) to *Acacia nilotica* (283 kg/ha). In addition, crude protein yield (kg/ha) was the highest in *Angeosis leocarpa* (267.1 kg/ha) and the lowest was in *Acacia nubica* (43.5 kg/ha) in Teltale district while in Dirre district, *Acacia nubica* (315.2 kg/ha) was the highest and *Acacia nilotica* (54.2) was the lowest.

Chemical composition of browse species in Borana rangelands is given in Table 3. Dry matter (DM) composition of the browse species ranged from 89.6% in *Angeosis leocarpa* to 95.7 % in *Commiphora africana* species. Ash composition of the browse leaves ranged from 6.8 to 15.7 % from Boswella *Commiphora* to *Acacia busei* and *Terminalia browni* respectively. The CP composition (% DM) varied from 13.8 % in *Boswella comphora* to 28.7 % in *Justica odora* species. The NDF composition of the browse species ranged from 25.4 % in *Justica odora* to 43.2% in *Boswella commiphora species*. ADF composition ranged from 11% in *Acacia drapanoloblum* to 19.2% in *Boswella Commiphora.* ADL composition ranged from 6.0 to 14.2% from *Ziziphus spina-Christi* to *Asparagus* species.

Phenolic composition (TP) of the browse species is shown in Table 4. The total phenolic concentration ranged between 19.1 to 31.4 % DM. Total tannin concentration (TT) ranged from 11.7 to 27.5% DM while condensed tannin concentration (CT) ranged from 3.2 to 19.4 % DM. Among the browse species, *Acacia toritlis* had significantly ($P<0.05$) higher concentration of phenols, total tannin and condensed tannin while *Justica odora*, *Asparagus* and *Ziziphus sipa–Christi* had the lowest TP, TT and CT respectively.

The mineral composition of the browse species is also presented in Table 4. Calcium concentrations (Ca) ranged from 1.43 to 2.15 % DM while phosphorous concentration (P) from 0.22 to 0.42 %DM of the leaf biomass. The lowest Ca was in *Acacia drapanolobium* and *Ziziphus spina–Christi* and the highest was in *Croton macrostachys*. On the other hand, the lowest P concentration was in *Acacia busei* and the highest was in *Commiphora Africana*.

The *in vitro* gas production of the studied species at different times of incubation is shown in Table 5. Gas volume after 24 hrs of incubation ranged from 24.3 to 51.2 ml /200 mg DM. The highest gas volume was from *Croton macrostachys* and the lowest gas was for *Acacia busei.* The gas volume after 48 hrs of

Table 2: Potential biomass and protein yields of browse species from Borana rangelands

			DM production					
	Plant/ha		kg/plant		kg /ha		CP yield (kg/ha)	
Plant Species	Teltale	Dirre	Teltale	Dirre	Teltale	Dirre	Teltale	Dirre
Aacacia brevisca	69^{e2}	130^{e1}	7.9^{e2}	14.8^{d1}	491^{i2}	899^{f1}	94.4^{f2}	170^{cd1}
Acacia busei	639^{a2}	980^{a1}	13.1^{d}	13^{d}	832^{d2}	1254^{b1}	$160b^{c}$	156^{cd}
Acacia drapanolobium	643^{a1}	167^{c2}	12.4^{d1}	19.1^{c2}	1126^{a1}	803^{h1}	$162b^{c2}$	241^{b1}
Acacia melifera	49^{e2}	99^{f1}	5.6^{f2}	11.4^{d1}	331^{m2}	649^{k1}	64.7^{g2}	126^{f1}
Acacia nilotica	98^{de}	98^{f}	11.2^{d}	11.2^{d}	291^{n1}	283^{r2}	55.5^{h1}	54.2^{k}
Acacia nubica	$58e^{2}$	113^{ef1}	6.7^{e2}	55^{a1}	225^{o2}	1803^{a1}	43.5^{i2}	315.2^{a1}
Acacia senegal	69^{e}	69^{g}	7.8^{e}	7.9^{e}	322^{m}	312^{q}	67.5^{gl}	74.5^{j}
Acacia seyal	204^{bc}	420^{b}	23.4^{b2}	48.1^{ab1}	487^{i2}	973^{e1}	115^{e2}	248^{b1}
Acacia toritilis	139^{cd}	138^{e}	16.1^{c}	15.9^{c}	701^{f1}	680^{j2}	185.2^{b1}	158^{cde2}
Acacia alibida	214^{bc}	213^{cd}	24.5^{b}	24.4^{c}	592^{f1}	573^{l2}	140.2^{d}	136^{d}
Angeosis leiocarpa	327^{b}	326^{bc}	37.2^{ab}	37.3^{b}	837^{d2}	1092^{c1}	267.1^{a}	250^{b}
Asparagus spp	207^{bc}	315^{bc}	23.8^{b2}	36.1^{b1}	578^{g2}	854^{g1}	119^{e2}	164^{d1}
Balanites aegyptica	140^{cd}	157^{d}	16.1^{c}	17.9^{d}	892^{c2}	969^{e1}	173^{c}	186^{c}
Boswella comiphora	83^{de}	83^{f}	9.2^{de}	9.5^{d}	353^{l}	343^{p}	69.1^{gl}	66.5^{k}
Cadaba farinosa	222^{bc}	221^{cd}	25.7^{b}	25.4^{c}	528^{h1}	512^{m2}	101^{e}	97.4^{h}
Carrissa spinarum	202^{bc}	201^{cd}	22.8^{b}	23.1^{c}	458^{j1}	445^{n2}	87.2^{f}	87.0^{hi}
Commiphora Africana	212^{bc}	256^{c}	24.3^{b}	29.4^{bc}	681^{f2}	800^{h1}	135^{d}	168^{cd}
Croton macrostachys	206^{bc}	205^{cd}	23.7^{b}	23.5^{c}	517^{h1}	501^{m2}	118^{e}	116^{gh}
Grewia bicolor	205^{bc}	204^{cd}	23.5^{b}	23.4^{c}	1040^{b1}	1009^{d2}	251^{a}	267^{b}
Justica odora	200^{bc}	199^{cd}	23^{b}	22.8^{c}	403^{k}	391^{o}	97^{f}	92.7^{i}
Rhus natelensis	146^{c}	126^{e}	16.8^{c1}	14.5^{d2}	692^{f1}	581^{l2}	164^{c}	138^{e}
Terminalia browini	207^{bc}	206^{cd}	23.4^{b}	23.7^{c}	750^{e1}	728^{i2}	178^{bc}	151^{d}
Ziziphus spina-christi	108^{d}	342^{bc}	39.8^{a}	39.3^{ab}	517^{h1}	508^{m2}	106^{e}	115^{g}
Mean±SE	168±29.1	210±32	19 ±1.2	24 ±6.2	593±27	737±0.1	127±6.8	156±8.4

DM=dry matter; CP= crude protein; $^{a, b, c, d, e, f, g, h, I, j, k}$ Mean in the same column with same letter are significantly different (P<0.05); $^{1, 2}$Mean in the same row under the same parameters are significantly different (P<0.05)

Table 3: Chemical compositions of selected browse species from Borana rangelands

		%DM				
Browse species	DM (%)	Ash	CP	NDF	ADF	ADL
Acacia busei	93.7^{ab}	15.7^{a}	15.9^{c}	33.4^{b}	15.8^{bc}	7.4^{d}
Acacia .drapanolobium	94.4^{ab}	10.3^{b}	22.8^{b}	25.5^{d}	11.0^{d}	7.0^{d}
Acacia toritlis	92.7^{bc}	7.1^{c}	20.5^{b}	33.2^{ab}	15.7^{bc}	9.2^{c}
Angeosis leiocarpa	89.6^{c}	9.7^{b}	19.2^{b}	29.3^{c}	16.8^{b}	13.7^{a}
Asparagus spp	93.0^{ab}	7.6^{c}	24.8^{ab}	43.2^{a}	19.2^{a}	14.2^{a}
Boswella comiphora	95.4^{a}	6.8^{c}	13.8^{d}	43.3^{a}	18.9^{a}	10.8^{b}
Carrissa spinarum	95.0^{ab}	8.7^{b}	21.1^{b}	30.1^{b}	16.0^{b}	11.6^{b}
Commiphora africana	95.7^{a}	9.0^{b}	14.3^{d}	28.4^{c}	14.4^{c}	8.3^{cd}
Croton macrostachys	95.4^{ab}	7.1^{c}	25.6^{ab}	34.9^{b}	18.4^{a}	9.4^{c}
Justica odora	95.3^{ab}	9.4^{b}	28.7^{a}	25.4^{d}	11.5^{d}	8.3^{cd}
Rhus natelensis	92.7^{bc}	8.2^{bc}	21.6^{b}	24.6^{d}	16.7^{b}	8.0^{cd}
Terminalia browini	93.7^{ab}	15.7^{a}	15.9^{c}	33.4^{ab}	15.8^{bc}	7.5^{d}
Ziziphus spina-christi	94.4^{ab}	10.3^{b}	22.8^{b}	25.5^{d}	11.2^{d}	6.0^{e}
Mean ±SE	94.0±1.7	9.7±2.9	20.5±0.4	31.6±4.5	15.1±2.8	9.4±2.5

$^{a, b, c, d, e, f,}$ Mean in the same column with same letter are significantly different (P<0.05); DM=dry matter; CP=crude protein; NDF=neutral detergent fiber; ADF= acid detergent fiber; ADL=acid detergent lignin

Table 4: Mineral and phenolic compositions of leaves of selected browse species from Borana rangelands

	%DM				
Species	Calcium	Phosphorous	Total phenol	Total tannin	Condensed tannin
Acacia busei	1.58^{ab}	0.22	31.4^{ab}	19.4^{b}	6.2^{c}
Acacia .drapanolobium	1.43^{b}	0.23	31.0^{ab}	17.8^{b}	13.2^{b}
Acacia toritlis	1.53^{ab}	0.34	38.4^{a}	27.5^{a}	19.4^{a}
Angeosis leiocarpa	1.89^{ab}	0.30	21.5^{d}	15.5^{c}	11.0^{bc}
Asparagus spp	1.76^{ab}	0.24	29.7^{b}	11.7^{e}	15.3^{ab}
Boswella comiphora	2.12^{a}	0.32	23.3^{d}	18.6^{b}	11.8^{bc}
Carrissa spinarum	1.44^{b}	0.38	20.8^{d}	19.0^{b}	15.8^{ab}
Commiphora africana	1.71^{ab}	0.42	26.3^{c}	17.5^{b}	16.1^{ab}
Croton macrostachys	2.15^{a}	0.23	28.6^{b}	15.5^{c}	13.6^{b}
Justica odora	1.93^{ab}	0.24	19.1^{d}	12.7^{d}	7.8^{c}
Rhus natelensis	1.89^{ab}	0.23	26.2^{c}	16.2^{c}	7.5^{c}
Terminalia browini	1.58^{ab}	0.22	21.4^{d}	19.4^{b}	6.2^{c}
Ziziphus spina-christi	1.43^{b}	0.23	21.0^{d}	11.8^{e}	3.2^{d}
Mean±SE	1.73±0.02	0.28±0.06	26.1±0.045	17.1±0.3	11.3±0.4

a, b, c, d, e, Mean in the same column with same letter are significantly different (P<0.05)

Table 5: *In vitro* gas production characteristics of selected browse species

	Gas volume (ml/200mg)			Gas production constants			
Browse Species	24hr	48hr	a (%)	b (%0	C(hr^{-1})	a+b(%)	LT (hr)
Acacia busei	24.3^{d}	40.4^{d}	13.9^{e}	65.0^{c}	0.013^{c}	78.9^{d}	5.09^{d}
Acacia dropanolobium	26.1^{d}	41.5^{d}	15.1^{d}	70.0^{b}	0.020^{b}	85.1^{b}	5.29^{cd}
Acacia toritlis	24.3^{d}	39.6^{d}	16.0^{cd}	50.0^{e}	0.022^{b}	67.0^{e}	5.60^{c}
Angeosis leiocarpa	46.7^{a}	52.1^{ab}	16.2^{cd}	65.4^{c}	0.024^{b}	81.6^{c}	5.93^{c}
Asparagus spp	39.4^{c}	44.8^{c}	16.5^{cd}	64.7^{c}	0.020^{b}	81.2^{c}	5.84^{c}
Boswella comiphora	33.6^{c}	39.0^{d}	19.3^{b}	74.4^{a}	0.024^{b}	93.7^{a}	6.10^{bc}
Carrissa spinarum	34.7^{c}	40.1^{d}	13.9^{e}	63.9^{c}	0.012^{c}	89.0^{ab}	5.02^{d}
Commiphora africana	42.7^{b}	48.1^{b}	13.8^{e}	76.0^{a}	0.022^{b}	89.8^{ab}	5.52^{c}
Croton macrostachys	51.2^{a}	56.6^{a}	17.4^{c}	78.5^{a}	0.043^{a}	85.9^{b}	7.33^{a}
Justica odora	48.3^{a}	53.7^{b}	19.5^{b}	63.0^{c}	0.034^{ab}	82.5^{c}	5.63^{c}
Rhus natelensis	46.8^{a}	52.2^{b}	23.0^{a}	58.6^{d}	0.026^{b}	81.6^{c}	6.59^{b}
Terminalia browini	41.5^{b}	46.9^{bc}	24.3^{a}	66.0^{c}	0.027^{b}	90.3^{ab}	7.05^{a}
Ziziphus spina-christi	36.1^{c}	41.5^{d}	13.9^{e}	65.0^{c}	0.014^{c}	78.9^{d}	5.09^{d}
Mean±SE	38.1±0.8	46.0±0.5	17.1±0.2	66.2±0.5	0.023±0.006	83.5±0.5	5.8±0.06

a, b, c, d, e Mean in the same column with same letter are significantly different (P<0.05); a= gas production from immediately soluble component; b=gas production from insoluble but potential degradable portion; a+b =potential gas production; LT= lag time

incubations ranged between 39.0 to 56.6 ml/ 200 mg DM. The lowest was for *Boswella comphora* and the highest was for *Croton macrostachys* leaves. The gas production from the soluble fraction (a) ranged from 13.8 to 24.3 %DM across the species. The highest value was for *Terminalia browni* and the lowest for *Comphora africana* species. The gas production from the insoluble but rumen degradable portion (b) ranged from 50.0 to 78.5 % DM.

The highest was for *Croton macrostachys* and the lowest was for *Acacia toritlis* leaves. Similarly, the rate of gas production © ranged from 0.012 to 0.043 /h. The highest was for *Croton macrostachys* and the lowest was for *Carissa spinara* species. The potential gas production ranged from 67.0 to 93.7 (%DM). The highest was for *Boswella comphora* and the lowest for *Acacia toritlis* leaves.

Table 6: Organic matter digestibility, Short chain fatty acids Metabolisable energy and Methane production of leaves of selected browse species

Browse Species	OMD (%) at 48h	ME (MJ/kgDM)	SCFA (mmol/L)	Methane production (ml/200mg)	MRP (%)	PF (ml gas/OMD)
Acacia busei	44.7^{d}	7.2^{d}	0.33^{f}	10.0^{cd}	55.5^{a}	1.47^{b}
Acacia dropanolobium	42.6^{d}	7.9^{c}	0.47^{e}	11.3^{cd}	47.9^{b}	1.77^{b}
Acacia toritlis	44.1^{d}	9.1^{b}	0.81^{d}	12.2^{c}	19.5^{d}	2.36^{a}
Angeosis leiocarpa	43.3^{d}	7.1^{d}	0.49^{e}	9.0^{d}	32.5^{c}	1.47^{b}
Asparagus spp	46.6^{c}	7.8^{c}	0.70^{d}	10.8^{cd}	42.9^{b}	1.54^{b}
Boswella comiphora	44.7^{d}	7.1^{d}	1.22^{c}	9.1^{d}	53.6^{a}	1.60^{b}
Carrissa spinarum	53.7^{b}	9.3^{b}	1.30^{c}	13.6^{b}	55.5^{a}	1.84^{b}
Commiphora Africana	43.0^{d}	9.3^{b}	1.67^{b}	13.6^{b}	56.4^{a}	2.12^{ab}
Croton macrostachys	52.0^{b}	10.4^{a}	0.51^{e}	15.0^{a}	23.1^{d}	2.33^{a}
Justica odora	58.0^{a}	10.3^{a}	2.01^{a}	15.0^{a}	21.5^{d}	1.90^{b}
Rhus natelensis	51.0^{b}	8.9^{b}	1.45^{c}	13.5^{b}	48.7^{b}	1.65^{b}
Terminalia browini	47.0^{c}	8.3^{c}	0.56^{e}	12.0^{c}	28.6^{c}	1.92^{b}
Ziziphus spina-christi	50.4^{bc}	9.0^{b}	0.62^{e}	12.7^{c}	57.5^{a}	2.07^{ab}
Mean±SE	47.8±0.24	8.6±0.9	0.93±0.5	12.1±1.6	41.8±1.4	1.84±0.22

$^{a, b, c, d, e,}$ Mean in the same column with same letter are significantly different (P<0.05); OMD=organic matter digestibility; ME= metabolizable energy; SCFA= short chain fatty acid; MRP=methane reduction potential; PF= partitioning factor

Table 7: Tannin biological activities of selected browse species from Borana rangelands

	Gas production (ml/200mgDM)									
	24h		48h		CH_4 production		SCFA production		ME (MJ/kg DM)	
Browse Species	PEG -	PEG+	PEG -	PEG+	PEG -	PEG+	PEG -	PEG+	PEG-	PEG+
Acacia busei	36.1^{b}	40.6^{a}	44.7^{b}	64.6^{a}	10.0^{b}	11.6^{a}	0.23^{b}	0.33^{a}	7.7^{b}	10.0^{a}
A. drapanolobium	29.4^{b}	44.8^{a}	42.6^{b}	66.9^{a}	11.3^{b}	12.3^{a}	0.29^{b}	0.47^{a}	8.1^{b}	11.3^{a}
Acacia toritlis	46.7	49.6	54.3^{b}	69.5^{a}	12.2^{b}	14.2^{a}	0.44^{b}	0.81^{a}	9.9^{b}	12.2^{a}
Angeosis leiocarpa	39.4^{b}	51.0^{a}	43.3^{b}	70.2^{a}	9.0^{b}	10.7^{a}	0.40^{b}	0.49^{a}	8.9	9.0
Asparagus spp	40.4^{b}	53.2^{a}	46.6^{b}	71.4^{a}	10.8^{b}	13.4^{a}	0.46^{b}	0.70^{a}	8.3^{b}	10.8^{a}
B. comiphora	47.3^{b}	50.7^{a}	54.7^{b}	70.0^{a}	9.1	9.4	0.77^{b}	1.22^{a}	8.1^{b}	9.1^{a}
Carrissa spinarum	42.7^{b}	55.2^{a}	53.7^{b}	72.5^{a}	13.6^{b}	15.1^{a}	0.91^{b}	1.30^{a}	7.7^{b}	13.6^{a}
C. africana	46.8^{b}	52.4^{a}	62.9^{b}	67.9^{a}	13.6^{b}	15.9^{a}	1.24^{b}	1.67^{a}	7.9^{b}	13.6^{a}
C.macrostachys	42.5^{b}	49.5^{a}	51.9^{b}	69.4^{a}	15.0^{b}	16.5^{a}	0.38^{b}	0.51^{a}	9.2^{b}	15.0^{a}
Justica odora	46.8^{b}	52.6^{a}	57.9^{b}	71.1^{a}	15.0^{b}	16.1^{a}	1.28^{b}	2.01^{a}	9.9^{b}	15.0^{a}
Rhus natelensis	41.5^{b}	54.4^{a}	51.0^{b}	72.0^{a}	13.5^{b}	14.5^{a}	0.73^{b}	1.45^{a}	8.9^{b}	13.5^{a}
Terminalia browini	36.1^{b}	42.8^{a}	46.9^{b}	65.8^{a}	12.0^{b}	14.5^{a}	0.21^{b}	0.56^{a}	8.3^{b}	12.0^{a}
Z. spina-christi	29.4^{b}	50.1^{a}	40.4^{b}	69.7^{a}	12.7^{b}	13.7^{a}	0.62^{b}	0.72^{a}	10.2^{b}	12.7^{a}
Mean±SE	40.4±4.8	49.8±3.3	50.1±5.5	69.3±1.9	12.1±1.6	13.7±1.7	0.6±0.29	0.9±0.3	8.7±0.5	12.2±1.6

$^{a, b,}$ Mean in the same row under the same parameters with same letter are significantly different (P<0.05);CT=condensed tannin; SCFA= short chain fatty acid; Me=metabolisable energy

Organic matter digestibility (OMD), short chain fatty acid production (SCFA), metabolisable energy yield (ME), methane production and methane reduction potential (MRP) from browse species are shown in Table 6. Organic matter digestibility (%) of the browse species ranged from 42.2 to 58.0 across the browse leaves. The highest was for *Justica odora* and the lowest was for *Acacia busei* leaves.

The short chain fatty acids (SCFA) production ranged from 0.33 to 2.01 mmol/litre in leaves of browse species. The highest was for *Justica odora* and the lowest was for *Acacia busei* leaves. ME production (MJ/kg DM) from the leaves ranged from 7.2 in *Acacia busei* to 10.4 in *Croton macrostachys* species. Methane production ranged from 9.1 ml in *Angeosis leocarpa* to 15 ml/200mg DM in *Croton macrostachys* and

Table 8: *In sacco* degradability characteristics of selected browse species

	DM degradability characteristics (%)					
Browse species	A	B	C	A+B	RSD	ED
Acacia busei	29.9^{a}	47.9^{c}	0.023^{d}	77.8^{b}	4.0^{a}	41.6^{b}
Acacia drapanolobium	26.1^{b}	52.1^{b}	0.020^{d}	78.2^{b}	3.1^{b}	37.4^{bc}
Acacia toritlis	22.0^{c}	48.8^{c}	0.033^{c}	70.8^{c}	2.7^{b}	43.2^{b}
Angeosis leiocarpa	24.1^{c}	52.3^{b}	0.040^{c}	76.5^{b}	3.0^{b}	49.8^{a}
Asparagus spp	23.1^{c}	45.3^{c}	0.040^{c}	68.4^{c}	3.0^{b}	41.7^{b}
Boswella comiphora	23.8^{c}	55.3^{b}	0.057^{b}	79.1^{b}	2.8^{b}	50.3^{a}
Carrissa spinarum	19.2^{d}	44.9^{c}	0.023^{d}	64.2^{c}	3.0^{b}	33.2^{c}
Commiphora africana	23.2^{c}	41.4^{d}	0.040^{c}	64.6^{c}	2.4^{b}	40.1^{b}
Croton macrostachys	23.0^{c}	59.9^{a}	0.050^{b}	82.9^{a}	3.1^{b}	57.5^{a}
Justica odora	26.1^{b}	49.3^{c}	0.080^{a}	75.4^{b}	3.1^{b}	53.2^{a}
Rhus natelensis	25.3^{b}	56.7^{a}	0.057^{b}	82.0^{a}	5.6^{a}	49.3^{a}
Terminalia browini	29.4^{a}	47.8^{c}	0.023^{d}	77.2^{b}	4.5^{a}	43.0^{b}
Ziziphus spina-christi	29.9^{a}	47.9^{c}	0.023^{d}	77.8^{b}	4.0^{a}	41.6^{b}
Mean±SEm	25.0±2.6	50.01±4.1	0.04±0.01	80.0±4.9	3.4±0.7	44.6±5.6

$^{a, b, c, d,}$ Mean in the same column with same letter are significantly different ($P<0.05$); A=immediately soluble fraction; B= insoluble but potential degradable fraction; C= rate of degradability for fraction B; A+B= potential degradability; RSD=residual standard deviation; ED= effective degradability

Justica odora leaves. Methane reduction potential (%) 12.2 % in *Grewia bicolor* to 57.5 % in *Ziziphus browni* species. Partitioning factor ranged from 1.47 in *Angeosis leocarpa* to 2.36 in *Acacia toritlis* leaves.

Tannin biological activity of the browse species on gas production, methane production, SCFA and ME production is presented in Table 7. Addition of polyethylene glycol (PEG) was observed to change gas production, OMD, ME and SCFA production from treated leaves while PEG had no effect on the above parameters for blank syringes. Increase in gas production on 24 hrs of incubation ranged from 6.2 % in *Acacia toritilis* to 70.4% in *Ziziphus spina-Christi* leaves while at 48 hrs of incubation increase in gas production ranged from 7.9 % in *Commiphora africana* to 72.5% in *Ziziphus spina-Christi* leaves. Methane production also increased from 3.3% in *Boswella comphora* to 24. % in *Asparagus spp* leaves while SCFA production ranged from 16.1% in *Ziziphus spina-Christi* to 166% in *Terminalia browni* leaves. On the hand, increase in ME production ranged from 1.1% *Angeosis leocarpa* to 76.6% in *Carissa spanara* leaves.

The *in sacco* degradability of the DM of the browse species is presented in Table 8. The instantly soluble fraction (A) of the browse species ranged from 19.2 % in *Carrisa spanara* to 30% in *Acacia busei* where the degradability of the insoluble but degradable fraction (B) ranged from 41.4% in *Comphora africana* to 64.2% in *Acacia busei* species.

The rate of degradability of the 'B' fraction (C) ranged from 0.02%/hr in *Acacia busei* and *Acacia draponolobium* to 0.08 %/hr in *Justica odora* species at 0.05 passage rate. Potential degradability (A+B) varied from 64.2 % in *Comphora africana* to 85.3 in *Acacia busei* leaves while effective degradability (ED) ranged from 33.2% in *Comphora africana* to 63.4 % in *Acacia busei* species.

DISCUSSION

Biomass Yield, Chemical and Phenolic Composition of Browse Species: In the current study, moderate to high plant density was observed both in Tetale and Dirre districts of Borana rangelands. This implies the grass lands are at risk of bush encroachment. Browse species such as *A. busei* in Dirre district and *A. dropanolobium* in Teltale district were the top invasive browse species in the study areas [30]. The leaf biomass and CP yield per ha observed in the current study revealed that the browse species studied had high leaf DM and CP yield to supplement the poor quality rangeland grass species during the dry season. Shimelis [31] reported the leaf biomass DM yield of browse species ranged from 77.6 to 871 kg/plant from *Cadaba farinosa* to *Balanities aegyptica* species in Nechisar national park. In the current study, *Angeosis leocarpa* and *A. nubica* were the browse species with the highest leaf biomass yield and CP yield (kg/ha) in Teltale and Dirre districts of the Borana rangelands respectively.

The nutrient composition of the studied browse species were comparable with a range of values reported by other authors in Ethiopia [31, 9] and tropical browse species reported by other researchers [12, 32]. However, there were slight variation in the chemical composition of the browse species which could be related to variation in species of the plants, soil type, climate and phonology of the browse species. Browse leaves of Borana rangelands could form potential feed resources mainly as protein supplements to ruminants fed on low quality basal forages such as rangeland grasses and crop by-products (straw, stover) that have low CP values (30-70 g/kg DM) especially during dry seasons. High CP values in browse species (138-256 g/kg DM) could correct deficient nitrogen in basal roughages. The current results of browse chemical compositions were comparable to those reported by other authors [33, 9]. Ondiek *et al*. [10] reported slightly higher CP (121-321 g/kg DM) from the Kenyan rangelands. However, some variations in CP could be due to proportion of foliage sampled for analyses as well as stage of maturity. For example, [34] reported low CP contents of 153, 153 and 219 g/kg DM in *A. toritlis*, *A. hockii* and *A. senegal* old leaves compared to high CP values (210, 194 and 319 g/kg DM) in newly emerged leaves, respectively. Rubenza *et al* [35] reported low CP contents in fruits harvested from *A. polyacantha* and *A. toritlis* compared to the respective species' leaves, is partly explained by genotype factors that control differential accumulation of nutrients in leaves and fruits (pods) as related to stage of maturity. High ash contents in browse to a large extent could be related to browse fodder nutritive potential with respect to mineral profiles. Lower fiber compositions (NDF, ADF and ADL or lignin) indicate promising nutritive potential in browse fodder. Low NDF content suggests feed of high cell contents (CC) that could be related to high feed digestibility. The current finding is in line with [5] who reported low fiber compositions in East African *Acacia* spp. However, low fiber fraction in tanniniferous browse may not reflect their actual nutritive quality. Most browse had low NDF, for example *A. toritlis* leaves and *A. dropalobium* (332 vs. 292 g/kg DM) that would suggest medium to high cell contents (CC). Increased CC in these browse forages could be due to soluble polyphenolic compounds, that would lead to underestimation of NDF, ADF and therefore over estimation of digestibility.

Acacia toritlis had high total phenolics and tannins that possibly could have interfered with fiber determination. High phenolics and tannins compositions in browse would depress feed nutritive values. The browse fodder (leaves and pods) had tannins greater than lower beneficial level (5 % DM) in animal feeding and nutrition [21]. High levels of phenolics and tannins ANFs could have adverse effects (depressed feed intake, impaired feed digestibility and toxic effect on rumen microbes) especially when fed in high proportions in ruminants' diets depending on nature and tannin activity. Relatively low polyphenolics composition in pod foliages suggests its superiority as a protein supplement to animals fed on low quality basal forages compared to browse leaves and soft and tender twigs. Accumulation of polyphenolics secondary plant metabolites represents a self-defence and adaptation mechanism in plants against foraging herbivores and insects; and even moisture stress. High polyphenolics in *Acacia* spp. has been reported elsewhere [33, 9], or other browse species [36, 37, 38]. Delphinidin, cyanidin and pelargonidin are products of leucodelphinidins, leucocyanidins and leucopelargonidins flavonoids, respectively, following cleavage of polymerized (condensed) tannin flavan in hot mineral acid- alcohol mixture. Delphinidins, cyanidins and pelargonidins represent flava-3-diol and flavn-3, 4-diols flavonoids or a mixture of the two; are the depolymerised constituents of leucoanthocyanidins (condensed tannins). Rubenza *et al*. [35] detected delphinidin, cyanidin and pelargonidin flavonoids in *A. polyacantha, A. toritlis, A. nilotica*; and *Dichrostachys* sp. leaves elucidate the structure, type and nature of tannin as related to tannin biological activity. Tannin molecules with different isomeric forms in their flavan have different tannin structure and possibly different biological activity; and would have variable tannin antinutritive activity whether *in vitro* or *in vivo*.

***In vitro* Gas and Methane Production:** Gas production is a result of feed fermentation *in vitro* that simulates the rumen degradability phenomenon. Gas production originates from feed fermentation and indirectly from CO_2 released from buffer mixture by volatile fatty acids (acetates, butyrates and propionates). The extent of gas production partly reflects efficiency of fermentation or extent of degradability of feed OM. Feed OM is fermented to microbial mass (microbial protein) and gases (CO_2; methane, CH_4) and short chain fatty acids (acetate, butyrate and propionate). Proportion of fermentation products depends on nature of feed, especially CP and fibre contents. Most of CP is degraded to microbial mass and gives less gas. Feed fermentation and digestibility determine nutritive values of browse and the two parameters are further influenced by chemical and phenolic compositions. A high GP indicates greater fermentation to support rapid rumen microbial growth.

In current study, the main factors affecting GP and IVOMD of browse were their ADL and tannin contents. These differences could be due to the difference in chemical structure of cell walls [39] and the molecular weight of tannins [40]. In the present study, tannin showed depressing effect in fermentation and digestibility of browses. *Croton macrostachys* was the most fermentable and digestible browse that could be associated to the low ADF, ADL and phenolic compounds. High gas production potential in *Croton macrostachys* and *A. toritlis* leaves suggest high extent and rate of feed fermentation. On the other hand, variable gas production within fodder species' foliages could be due to nature and proportion of fibre in the feed sample. Decreased degradability could mostly explained by phenolics and tannins binding feed nutrients in the process of fermentation. Similar observations were reported by other authors [41, 42, 43]. High feed *in vitro* degradability estimates indicated by gas production in *A. nubica* different from expectations due to high phenolics and tannins could be attributed to specific nature of tannin activity as related to biological anti-nutritive activity. In agreement to the current studies, different researchers had reported negative effects of plant phenolic compounds on their fermentation and digestion [44, 45]. The negative effect of tannin on fermentation and digestion could be related to the formation of tannin-carbohydrate complex that are less degradable or toxic to rumen microbes [46]. Some of variations could be due to plant genotypic characteristics in relation to type of phenolics and tannins' activity on digestibility.

Makkar and Becker [41] reported a variable nature of tannins between and within plant species as related to their nature and biological activity. Similarly, observed differences on degradability both between fodder species and foliage components could be due to fibre type and extent of lignifications [47]. High gas production from *Croton macrostacys* at initial incubations (3 h and 6 h) could be explained by high CP. CP represents a large proportion of an immediately fermentable OM feed fraction at initial incubations and decreases at subsequent incubations.

The reflected high gas production from *Croton macrostachys* could be explained by low fibre composition though had high total phenolics and tannins. Results suggest that polyphenolics in *A. nilotica* had less depressive effect on gas production. Also low fibre could probably have less effect on depressed OM degradability *in vitro*. Based on gas production potential in leaves, *Acacia busei* ranked lowest followed by *Dichrostachys* sp., A. *toritlis* and *Croton macrostachys* (the highest). This trend could be due to amount of lignin and extent of lignifications and possibly due to level of tannin and related biological activity. The constant "a" represents the immediately fermentable DM fraction. The "b" constant denotes a slowly fermentable feed fraction with time. The constants "a" and" b" are mainly related to type of fibre and extent of fibre lignifications and plant genotype.

Enteric methane production primarily depends on the quantity and quality of the diets as it affects the rate of ruminal digestion and passage [48]. Production of methane is a sink for hydrogen in the rumen during the process of utilization of feed energy. However, with fermentation of tannin rich plants, their bactericidal and bacteriostatic effects on the rumen microbes and inactivation of their enzymes greatly suppress fermentation and this could result in decrease of methane production. In this study, browses with higher phenolic contents generally produced lower methane regardless of their CP, NDF, ADF and lignin contents. Inclusion of PEG in browse samples resulted in increased in methane production which might be due to digestion and acetate shift VFAs production. The impact of the tannins on rumen methanogenesis was more pronounced than their effect on substrate degradation [49]. The decrease in methane production with inclusion of tannin in ruminant diet was similarly reported by several researchers [50, 45].

Tannin Biological Activities: Increased in values of gas volume, ME, SCFA and methane production by addition of PEG to the browse species under this study revealed that the availability of the soluble nutrients for fermentation were depressed by the effects of the condensed tannins in the browse species. Jayanegara *et al*. [44] conducted a meta-analysis and concluded that increasing tannin concentrations consistently suppressed CH_4 production under *in vitro* and *in vivo* condition. PEG binds tannins and deactivates tannin anti-nutritive activity on lowered nutritive values. Therefore, observed responses on improved gas production, OMD and ME values due to PEG treatment mainly reflects deactivation of tannin activity in tanniferous browse. Makkar *et al*. [42] and Getachew *et al*. [43] reported improved gas production and digestibility estimates due to PEG binding tannins anti-nutrient factors in *Dichrostachys* sp. For example, incubation of browse fodders with PEG MWT 4 000 and 6 000 improved OMD from 25.3 to 39.5% and from 25.3 to 42.5% in *Croton macrostachys*, respectively, [42]. Improved OMD and ME due to addition of PEG represent nutritive potential in browse foliages previously depressed by tannin activity. This follows the fact that PEG has high affinity for tannins [42]. Relatively lower response in pod foliages due to PEG treatment indicate relatively higher nutritive potential that could be due to lower phenolics amount compared to those in leaves.

***In sacco* Degradability Characteristics:** *In sacco* degradability DM disappreance and estimated parameters in the current study revealed that the browse leaves had medium to high potentials to supplement the poor quality rangeland grasses during the critical shortage feeds. The soluble fraction 'A' values of the browse species (19.2-30 % DM) and the potential degradable fraction 'B' (41.4-60% DM) were with the range reported by [38] and [32]. The effective degradability in this study (41.6-57.5 % DM) revealed that the leaves had potential nutritive values for dry season supplementation for the grazing livestock.

CONCLUSION

From this study it was concluded that browse leaves from Borana rangelands could be used as protein supplements to ruminants fed on poor quality roughages due to high protein and low to medium fiber contents compared to basal roughages. However, high tannin (>10% DM) in these browse legumes could limit optimal utilization of browse fodders due to depressed feed digestion as was demonstrated by PEG tannin bioassay. Improved digestibility due to PEG treatment represents nutritive potential previously depressed by tannins' anti-nutritive activity. PEG binds tannins, deactivates tannin anti-nutritive activity and recovers nutrients previously bound by tannins. The PEG bioassay demonstrated treatments of the browse species could be appropriate for utilization of tanniferous browse by reducing tannin levels. *In sacco* degradability experiment ranked the browse species in the following decreasing order: *Croton macrostachys> Rhus natelensis>Boswella comiphora>Acacia drapanolobium>Acacia busei, Ziziphus spina –Christi>Terminelia browini > Angeosis leiocarpa> Justica odora>Acacia toritilis> Asparagus spp> Carrisa spanara>Commiphora Africana.* Therefore, utilization of browse fodder could be optimized by either reduction of phenolics and tannins levels in browse, or feeding of a mixture of feeds with readily available nitrogen together with tanniniferous browse to dilute tannin anti-nutritive activity. Further studies are recommended on assessment of these browse fodders for in *viv*o nutrient utilization through intake, digestibility and animal performance trials.

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