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Chemical Composition, *In vitro* Digestibility and Gas Production of Selected Forages Preferred by Dromedary Camels in Peri Urban Area of Isiolo Town, Kenya

Cyrila I. Lusala[1], Levi M. Musalia[2], James G. Kirimi[1] & Florence K. Thiakunu[3]

[1] Department of Livestock and Fisheries Development, Meru County Government, P.O. Box 185-60202, Nkubu, Kenya

[2] Department of Dry Land Agriculture and Natural Resources, Tharaka University, P.O. Box 193-60215, Marimanti, Kenya

[3] Department of Animal Science, Meru University of Science and Technology, P.O. Box 972-60200, Meru, Kenya

Correspondence: James G. Kirimi, Department of Livestock and Fisheries Development, Meru County Government, P.O. Box 185-60202, Nkubu, Kenya. E-mail: kirimijg@yahoo.com

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Abstract

Inadequate feed resources in quantity and quality during dry season is the major factor affecting milk production in lactating dromedary camels under the peri-urban production system. This study aimed to evaluate the nutritive contribution of selected shrubs and fodder species to lactating camels in peri urban area of Isiolo town, Kenya during dry season. Nineteen samples of different browse species were collected based on palatability and analyzed for proximate composition, detergent fiber fractions, *In vitro* digestibility and gas production. Average dry matter (DM) percentage on all dried sampled shrubs was 90%. The crude protein (CP) content ranged between 4.98 - 26.66%. The neutral detergent fibre (NDF) and acid detergent fibre (ADF) values ranged from 24.90 - 72.85% and 19.02 - 55.85% respectively. Organic matter digestibility (OMD) and dry matter digestibility (DMD) mean were 47.32% and 41.25% respectively. *Acacia nilotica* had highest OMD (75.29%) and DMD (62.80%) while *Prosopis cineraria* recorded the lowest at 24.21% and 22.10% respectively. Cumulative gas production was high in *Haloxylon salicornicum* (0.00-70.43ml/200mg) and low in *Zizyphus mucronata* (23.31ml/200mg) with increasing incubation time from 2 to 15 hours. The results indicate that the nutritive values of the forages were not adequate hence supplementation is required for dromedary camels during dry season in peri urban production system. Proper management and conservation of the rangelands through reseeding will also improve the forages nutritional composition.

Keywords: browse, chemical composition, *In vitro*, gas production, Isiolo, peri urban

1. Introduction

The dromedary camel is known for its ability to survive drought periods and camel milk has been called the white gold of the desert (Wernery, 2006). Water, dry matter intake (DMI), and nutrient quality of the feed affect milk production. Determination of camel productivity depends upon the amount and nutritive quality of vegetation available for browsing. Camel's feed intake depends primarily on its selective feeding of a wide variety of vegetation and different parts of forage browse which differ in quality. The vegetation is often sparse in the dry-lands and camels graze large areas to satisfy their nutritional needs and have to walk considerable distances to find water (Dahlborn, 2000).

Continuous increase in human population for livelihood and multiplying number of livestock is adding towards pressure on the available resources and minimizing the browse selection base for camels (Akhter & Arshad, 2006). Varying climatic changes over time due to climate change makes nutrient availability less by biodiversity loss in the peri urban area. Rainfall has become irregular and unpredictable compared to previous years, while frequency of droughts has become more and severe flooding during the short rains. Consequently, heterogeneous forages dry up or completely disappear from the ecosystem resulting in insufficient supply of forage feed in terms of biomass and quality nutrition leading to reduced milk yield from camels. The ability of most browse species to remain green for a longer period is attributed to deep root systems, which enable them to extract water and nutrients from deep in the soil profile and this contributes to the increased CP content of the foliage (Le Houerou, 1980).

However, the situation is made worse by the restriction of grazing in the peri urban system where camels may not have the advantage of roaming around freely in the urban vicinity hence limited feed species. One of the main constraint to peri urban camel production system is seasonality of feed availability and where available, most species are inadequate in nutrients (Noor et al., 2012). Under the same study by Noor et al. (2012), native grasses and *Euphorbia tirucalli* were more important for feeding camels in peri urban system than pastoral. According to Maundu and Tengnas (2005). *Euphorbia tirucalli* is good fodder for camels during severe feed shortage and reportedly improves the health of weak camels but its nutritive value and possible effects on camel products are unknown.

Inadequacy of essential nutrients and minerals in the available forages in camel nutrition as reported by Kuria et al. (2004) generally affect camel productivity in peri urban pastoral areas. For instance, proteins are fundamental components of all living cells because it is building unit of enzymes, hormones and antibodies, which are necessary for the proper functioning of the camel. For growth and repair of tissue, proteins are essential in the diet of camels (Hussain et al., 2009). 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).

However, chemical composition of plants in range-lands varies according to species, soil type, climate, phenology and abiotic factors (Khan et al., 2005). Range-lands show a great diversity of species composition, structure, productivity and ultimately their capacity to support livestock. Therefore, sustainable use of these range-lands is essential for the provision of forage to livestock (Majeed et al., 2002). Daily milk yield of camels vary from 3.5 liters under desert conditions to 40.0 liters under very intensive management (Khan, et al., 2003; Farah et al., 2004, Adongo et al., 2013). The current study therefore was conducted to determine chemical composition, degradation, fermentation and absorption for utilization through organic and dry matter digestibility of the available camel forages.

2. Materials and Methods

2.1 Study Site

The experiment was conducted at Ewaso Ng'iro North Development Authority (ENNDA), Camel Research Centre in Ngaremara, Isiolo County. Proximate analysis, *In vitro* digestibility and gas production was done at Kenya Agricultural and Livestock Research Organization (KALRO) Muguga.

2.2 Collection of Samples

The available fodder and shrubs were identified by key informants who availed information on types of browse species available, vernacular names, season favored, palatability, parts of plants eaten and relative attractiveness to camels. Nineteen samples were collected in this study during the dry season, where small branches with leaves were taken for analysis. The collected samples were the commonly browsed species with each sample being picked from three shrubs to avoid bias.

2.3 Chemical Analysis

Initial drying was done at 60°C to air dry samples for further analysis following AOAC (2000) procedures. The selected forage samples were analyzed for; dry matter (DM), crude protein (CP), ether extract (EE), ash, crude fibre (CF), neutral detergent fiber (NDF), acid detergent fibre (ADF), acid detergent lignin (ADL) and energy. Dry matter (DM) was determined by air-drying 2g of the samples in an oven at 105°C for 8 hours and getting the difference in weight as moisture content. Nitrogen determination was done using the micro- Kjeldahl method. Ether extract was done by solvent extraction using soxhlet extractor as described in AOAC (1995). Each sample was set in three clean round bottomed flasks in an oven at 105^0C for 1 hr then cooled in desiccator and weighed. Crude fibre was determined by putting 2 grams of air-dried sample in a 500ml graduated glass beaker and 25mls of hot water added, followed by 25mls 2N H2SO4. Ash content was determined by weighing approximately 2g of sample into a pre-weighed crucible and placed in a muffle furnace set at 550^0C for 4hrs. Gross energy was measured with the help of oxygen bomb calorimeter. Neutral detergent fibre (NDF), acid detergent fibre (ADF) and acid detergent lignin (ADL) were analyzed according to Van Soest et al. (1991).

2.4 In vitro Gas Production

Evaluation and ranking of the nutritive value of the fodder and shrubs was done through gas production due to rumen liquor fermentation of substrate to volatile fatty acids by incubating with rumen liquor and the volume produced used to estimate the organic matter digestibility and metabolizable energy yield.

Determination of *In vitro* dry matter and organic matter digestibility was done at 24-hour incubation of samples (Zailan et al., 2016).

An estimate of gas production characteristics was done by fitting the mean gas volumes to the exponential equation of Orskov and McDonald (1979):

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

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)

2.5 In vitro Organic and Dry Matter Digestibility

The OM of dry residue was determined by the incineration of muffled furnace at 550^{o} C for 3 hours. The *In vitro* Organic Matter Digestibility (IVOMD) was calculated by:

$$\text{IVOMD}\ (\%) = \frac{\text{Initial Organic Matter (mg)} - \text{Residual Organic Matter (mg) x 100}}{\text{Sample Organic Matter}} \tag{2}$$

(Zailan et al., 2016)

In vitro dry matter digestibility (IVDMD) was carried out using modified Tilley and Terry (1963) digestion technique using cecum fluid obtained from a slaughtered camel steer fed on mixed natural range vegetation. *In vitro* dry matter disappearance was evaluated using the formula:

$$\text{IVDMD}\ (\%) = \frac{\text{(Initial dry sample wt.)} - \text{(Residue – Blank) x 100}}{\text{(Initial dry sample wt.)}} \tag{3}$$

(Osuga et al., 2020)

The blank value was determined by incubating a tube containing rumen liquor and buffer, with no feed sample to determine indigestible materials introduced into the vessel by the rumen fluid inoculates.

2.6 Data Analysis

Proximate, gas production, organic matter and dry matter digestibility data on forages and shrubs, were subjected to descriptive statistics as dependent variables to make comparisons. Excel was used to get the mean, standard deviation and coefficient of variance.

3. Results

3.1 Proximate Composition of Shrubs and Fodder

Proximate composition of the conventional shrubs and fodder is shown in Table 1. *Acacia mellifera* had the highest dry matter (93.99%) content. The CP mean for all samples was 15.56% with *Salvadora persica* recording the highest CP content (26.66%) and *Boscia coriacea* lowest (4.98%). NDF was high in *Cordia quercifolia* (72.85%) and low in Haloxylon *salicornicum* (24.90%) and a mean of 56.11% for all the samples. ADF had a mean of 40.95% for all the samples with *Zizyphus mucronata* recording high at 55.85% and low in *Haloxylon salicornicum* at 19.02%. *Cordia quercifolia* was the most lignified shrub (ADL) at (20.67%) while *Haloxylon salicornicum* (5.89%) was least lignified. Ash was highest in *Haloxylon salicornicum* at 19.43% and lowest in *Salvadora persica* at 5.83%. Ether extract ranged from 9.36% to 17.19% for the samples with *Haloxylon salicornicum* recording high at 17.19% and *Calotropis procera* low at 9.36% respectively. Metabolizable energy had a mean of 9.00% with *Haloxylon salicornicum* at 13.51% *and Zizyphus mucronata* at 5.99%.

Table 1. Proximate Composition (%) of Selected Shrubs and Fodder

	Proximate (%)	**DM**	**CP**	**EE**	**Ash**	**NDF**	**ADF**	**ADL**	**ME(Kj)**
Scientific Name	Local Name								
Calotropis procera	Ekorokoroite	92.82	14.71	9.36	9.97	55.35	43.01	15.50	8.19
Capparis decidua	Ethigirait	90.23	19.30	12.26	16.93	46.75	32.30	7.52	10.61
Haloxylon recurvum	Edung	92.09	12.40	10.01	7.78	64.44	45.17	14.25	8.65
Haloxylon salicornicum	Ethekon	86.71	15.40	17.19	19.43	24.90	19.02	5.89	13.51
Zizyphus mucronata	Logolito	91.92	6.19	9.59	7.20	69.08	55.85	20.43	5.99
Acacia nilotica	Engomo	91.78	9.82	10.71	7.69	68.06	51.53	15.54	8.66
Acacia mellifera	Lomunyani	90.25	19.40	12.70	12.24	43.45	39.25	12.31	12.43
Prosopis cineraria	Epetet	92.37	12.32	11.58	6.04	61.81	41.54	13.23	8.95
Calligonum polygonoides	Murumuru	90.92	19.11	11.65	13.45	45.85	38.59	16.27	11.58
Tamarix aphylla	Edung chopot	92.96	14.78	10.10	5.96	68.77	40.29	15.63	6.61
Salvadora persica	Erut	91.57	26.66	11.34	5.83	51.73	36.95	14.25	8.46
Euphobia tirucali	Eputhkou	89.60	23.84	17.09	15.56	33.69	20.29	10.23	12.34
Acacia brevispica	Epipa	93.99	18.25	9.57	8.00	70.54	53.19	15.81	6.83
Indigofera spp	Arikoi	91.03	17.35	13.56	10.61	50.93	41.25	9.08	10.62
Cordia sinensis	Ereng	92.17	16.94	10.70	9.22	60.54	41.37	14.27	8.68
Boscia coriacea	Epung'ae	92.16	4.98	11.71	6.75	61.14	52.10	18.82	7.17
Lycium europeum	Ekabonyoo	90.46	21.00	11.38	16.50	52.69	30.62	7.12	7.06
Cordia quercifolia	Ekabekebeke	91.95	13.09	10.45	6.97	72.85	53.84	20.67	6.88
Kleinia spp	Ekwanga	92.65	10.02	11.16	8.68	63.48	41.85	13.04	7.86
	STD Mean	90.90	17.40	12.35	14.11	61.10	37.11	7.19	8.25
	STDEV	0.049	0.099	0.093	0.071	0.707	0.707	0.328	0.163
	CV%	0.05	0.57	0.75	0.50	1.16	1.91	4.56	1.98

Note: DM- dry matter; CP- crude protein; EE- ether extract; NDF-neutral detergent fibre; ADF-acid detergent fibre; ADL-acid detergent lignin; ME- metabolizable energy.

3.2 Shrubs and Fodder Gas Production

Measurements were of 24h gas production of 19 forage species using rumen liquor from a grazing cow. Cumulative gas production increased rapidly with incubation time from 2 to 15 hours and remained relatively stable from 19 to 24 hours for most forages (Table 2). The analytical method used was gas chromatography with the highest quantity of gas obtained from *Haloxylon salicornicum* (70.43ml/200mg) and the lowest quantity from *Zizyphus mucronata* (23.31ml/200mg). The negative values depict high lignin content which inhibits microbial activity in fodder degradation leading to low gas production.

Table 2. Gas Production (ml/200mg) of Selected Shrubs and Fodder

		Time (Hours)								
Shrubs/forage		**2**	**4**	**6**	**8**	**10**	**12**	**15**	**19**	**24**
Scientific Name	**Local Name**									
Calotropis procera	Ekorokoroite	-0.74	2.37	7.12	7.71	14.82	17.19	23.70	32.43	35.98
Capparis decidua	Ethigirait	-3.65	-0.84	2.63	5.77	17.01	20.48	30.55	41.94	50.53
Haloxylon recurvum	Edung	-2.93	-1.61	1.60	4.95	13.69	16.46	22.87	32.49	40.07
Haloxylon salicornicum	Ethekon	0.00	4.06	10.34	16.21	28.55	31.79	42.51	58.69	70.43
Zizyphus mucronata	Logolito	-3.79	-1.32	1.87	4.77	12.60	13.18	17.81	24.33	23.31
Acacia nilotica	Engomo	-9.67	-4.69	-0.75	3.78	13.70	17.05	25.07	34.70	40.97
Acacia mellifera	Lomunyani	-3.46	2.03	6.26	11.27	21.12	27.07	39.11	55.07	63.68
Prosopis cineraria	Epetet	-3.01	-1.44	0.42	3.13	10.83	14.25	23.09	31.64	41.62
Calligonum polygonoides	Murumuru	-3.79	-1.75	2.51	6.92	17.30	21.71	31.77	45.94	58.06
Tamarix aphylla	Edung chopot	-2.85	-1.14	0.56	2.68	9.48	11.18	16.55	22.07	24.05
Salvadora persica	Erut	-4.62	-1.45	1.14	3.87	12.19	16.07	23.68	28.56	32.15
Euphobia tirucali	Eputhkou	-4.11	-2.14	0.64	6.20	16.83	19.93	29.90	46.25	58.35
Acacia brevispica	Epipa	-3.16	-2.02	-0.58	4.14	10.43	11.14	16.14	22.00	24.43
Indigofera spp	Arikoi	-6.73	-4.13	0.74	9.89	18.26	23.44	33.48	40.94	50.68
Cordia sinensis	Ereng	-3.86	-1.05	2.21	7.98	14.18	17.73	24.53	33.24	38.12
Boscia coriacea	Epung'ae	-5.79	-2.47	-0.74	5.76	10.51	13.39	17.56	25.49	31.54
Lycium europeum	Ekabonyoo	-11.35	-11.67	-10.85	-5.11	0.78	3.40	8.97	17.49	24.20
Cordia quercifolia	Ekabekebeke	-4.07	-1.61	0.28	7.08	11.85	13.73	17.64	24.00	26.60
Kleinia spp	Ekwanga	-6.46	-5.58	-3.83	1.88	10.07	12.85	20.01	28.93	34.77

3.3 Organic Matter (OMD) and Dry Matter Digestibility (DMD) of Forages

Organic matter and dry matter digestibility of forages is shown in Table 3. Organic matter digestibility (OMD) and dry matter digestibility (DMD) mean were 47.32% and 41.25% respectively. Organic matter digestibility for the 19 forage samples was in the range of 75.29-24.31% while dry matter digestibility was in the range of 62.80-22.10%. *Acacia nilotica* recorded the highest OM (75.29%) and DM (62.80%) digestibility while *Prosopis cineraria* recorded the lowest at 24.21% and 22.10% respectively.

Table 3. Organic Matter (OMD) and Dry Matter (DMD) Digestibility of Forages

Shrubs/Forages		**Digestibility (%)**		
Scientific Name	**Local Name**	**OMD**	**DMD**	**DMD (OM/Kg DM)**
Calotropis procera	Ekorokoroite	38.23	31.24	305.89
Capparis decidua	Ethigirait	51.37	42.34	429.20
Haloxylon recurvum	Edung	39.77	37.19	356.77
Haloxylon salicornicum	Ethekon	47.67	39.21	389.33
Zizyphus mucronata	Logolito	44.47	41.48	409.96
Acacia nilotica	Engomo	75.29	62.80	623.10
Acacia mellifera	Lomunyani	54.61	44.72	439.45
Prosopis cineraria	Epetet	24.21	22.10	242.00
Calligonum polygonoides	Murumuru	54.08	42.90	428.90
Tamarix aphylla	Edung chopot	46.25	44.00	430.03
Salvadora persica	Erut	33.25	30.79	289.44
Euphobia tirucali	Eputhkou	51.73	43.00	450.18
Acacia brevispica	Epipa	50.03	43.44	467.00
Indigofera spp	Arikoi	45.44	42.73	423.18
Cordia sinensis	Ereng	40.78	38.30	375.14
Boscia coriacea	Epung'ae	46.15	43.00	428.76
Lycium europeum	Ekabonyoo	35.26	30.66	320.40
Cordia quercifolia	Ekabekebeke	60.38	49.58	484.67
Kleinia spp	Ekwanga	60.04	54.32	531.23
Mean±SD		47.32	41.25	

4. Discussion

4.1 Chemical Composition of the Shrubs

Proximate results in this study (Table 1) show variation in chemical composition of forages indicating inter species differences. Factors such as plant part, harvesting regime, season and location that influence palatability, rumen degradability, digestibility, voluntary intake and nutrient utilization by animals could have contributed to the high variability in the nutrient content of browse due to within species variability (Solomon, 2001).

Dry matter (DM) in forages is the actual amount of feed stuff exclusive of water, volatile acids and bases if present (Azim et al., 2011). In this study, high DM content was recorded in browse species, which could have resulted from maturity of foliage at sampling as it increases with maturity of forages (Sanon et al., 2008). Dry matter (DM) content observed in this study corresponds with the finding of Kuria et al. (2012) who reported 91.1% of mean DM content of preferred browse species by camels. The values ranged similar to those reported by Njidda and Ikhimioya, (2010) as well. Dalle (2020) and Nsubuga et al. (2019) reported similar findings that the DM concentration of edible browse species range from 88% to 93% in arid and semi-arid regions, which is consistent with the current findings.

Protein deficiency leads to reduced appetite, reduced feed intake and poor feed efficiency which results in poor growth and development of animals. The minimum requirement CP is (7%) for sustainability of rumen microbes which was satisfactory for shrubs and fodder in this study except for *Zizyphus mucronata* (6.19%) and *Boscia coriacea* (4.98%) (Lazzarini et al., 2009). Crude protein (CP) content ranged from (4.98% to 26.66%) with a mean (15.56%) which was lower compared to a report by Kuria et al. (2005) indicating low CP content during dry season. The CP differences among the forage samples could also be due to stages of growth and the amounts of leaves and twigs picked for the sampling. Crude protein (CP) content also decreases with maturity while the fibre content increases. Therefore, the forages could be a source of good quality protein if degradation was optimum and non-toxic to the microbes of rumen.

Animals mainly derive their energy from ether extract (EE) for production and maintenance which is a component of lipid. A high EE in feed samples is a sign of higher energy level for the animals (Odedire and Babayemi, 2008). In this study, maximum value of EE was 17.19% (*Haloxylon salicornicum*) and minimum 9.36% (*Calotropis procera),* which was comparable with that reported by Mahala et al. (2009). Crude fat content of the sampled browse species were within the range of 1%–20% EE on DM basis, the amount often found in livestock formulations (Galyean, 2009).

Ash is the mineral level in animal feed, consisting of calcium, phosphorus, potassium and a large amount of silica which promotes balanced growth of animals. The concentration of ash in this study ranged from 19.43% *(Haloxylon salicornicum)* to 5.83% (*Salvadora persica)* with mean value 10.25%. Through different research, varying ratios of ash in different species have been reported in a range of 07.60% and 22.20% (Tan & Yolcu, 2001). Ash figures in this study were within the same limit comparable by an earlier study results (Sultan et al., 2010). Similar to this study finding, Kilcher (1981) also reported that ash content of forage progressively decline with advancing maturity.

Crude fibre (CF) content varies depending on the season. As forage become older, the Crude Fibre (CF) tends to increase. In this study, all fodder samples had high fibre content except for *Haloxylon salicornicum* which had 24.90%, 19.02% and 5.89% respectively for NDF, ADF, ADL implying they were quite mature as a result of the prolonged dry weather. Findings of Melaku et al. (2010) who revealed values of NDF ranging from 28.2% to 53.5% in dry season were slightly lower compared to this study. A rise in NDF proportion would definitely reduce energy density, feed intake and productivity of dairy animals (Kanjanapruthipong et al., 2001; Mertens, 1997), whereas a lower content would alter rumen fermentation leading to severe acidosis. The fiber component, mainly NDF, ADF and ADL in the browse species increase depending on maturity, with variations between and within species (Reed, 1986). It is well established that lignin content in forages is negatively correlated with digestibility and the main anti-quality factor of lignin in forages limits the digestion of the structural carbohydrates, mainly cellulose and hemicellulose (Zailan et al., 2016). However, lignin structure is beneficiary to the plants as it gives support to the plant structure, limits water loss by reducing the permeability of the cell wall and impedes pathogens. Describing the nutritive value of forages is important as measured by the NDF, ADF and ADL content. Neutral Detergent Fibre (NDF) is directly 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).

Metabolizable energy (ME) is the gross feed energy exclusive of energy lost in feces, urine and gaseous product of digestion which is crucial for utilization. Evitayani et al. (2004) reported a lower ME of between 6.1 to 9.2 KJ/Kg DM for forages compared to the one in this study (5.99 to 13.51 KJ/Kg DM). Menke and Steingass (1988) noted a strong correlation between ME value measured *In vivo* and ME from 24 h *In vitro* gas production and crude protein content of the forages under prediction. In the present study, *Haloxylon salicornicum* had the highest (13.51KJ/Kg) ME content. An indication that ME content was very consistent with nutrient content, digestibility and gas production of these forages.

Different browse forages increase feeds variety to the animal and also reduces over dependence on one browse species by the camels. These complexes lower negative impacts of tannin in the rumen by altering the microbial activities (Rogosic et al., 2008). High levels of ash in the forage are a crude indicator of total mineral content in the feed in addition to other materials of organic origin such as Sulphur and phosphorus from proteins. High digestibility in the browse species indicates the extent at which the nutrients are being degraded and their suitability for use in feeding camels particularly during dry season when there is feed scarcity and less digestibility in the available species (Getachew et al., 2000).

4.2 In vitro Gas Production, Organic and Dry Matter Digestibility

In vitro cumulative gas produced varied with time among the selected browse forages. The cumulative gas production ranged from 23.31ml/200mg in *Zizyphus mucronata* to 70.43ml/200mg in *Haloxylon salicornicum* over 24 hours of incubation. *Acacia mellifera, Euphobia tirucali, Calligonium polygonoides* and *Haloxylon salicornicum* had the highest (63.68ml/200mg, 58.35ml/200mg, 58.06ml/200mg and 70.43ml/200mg respectively) potential gas production, while *Lycium europium, Acacia nilotica, Acacia brevispica Cordia quercifolia* and *Zizyphus mucronata* had the lowest gas production potential at 24.20, 40.97, 24.43, 38.12 & 23.31ml/200mg respectively. The differences in browse forages for *in vitro* gas production and fermentation characteristics agree with previous studies on similar forages from East Africa (Abdulrazak et al., 2000; Osuga et al., 2007) where all the species in this study had a wide range of 70.43 to 23.31ml/200mg. Gas production results from fermentation of the feed to short chain fatty acids (SCFAs) released from the buffering of the produced SCFAs by bicarbonate buffer. Amount of substrate fermented and the SCFAs produced upon substrate fermentation could have resulted in differences in gas production among the species in this study. Chemical composition differences especially the CP, fibre and tannin could have also contributed to the differences in the rates and extent of the fermentation of forages. For instance, the comparatively low CP and high fibre content in *Acacia nilotica* could be related to low extent and rate of gas production. Osuga et al. (2007) also reported *Acacia nilotica* to contain high levels of tannin, which could have contributed to the lower gas production and fermentation in this experiment.

Organic (OM) and dry matter (DM) digestibility of the fodder samples in Table 3 indicates how feed can be broken down by microbes and digestion enzymes. According to Orskov (1979), the fermentation process increases nutrients, especially protein. Ruminal microbes require energy as the main essential factor for growth and maintenance (Bamualim, 1994). Digestibility varied among the fodder species due to composition differences, maturity stages and the parts that were selected for analysis (Nanda et al., 2014). Crude fiber level also affects feed degradation whereby a higher crude fiber content lowers degradation (McDonald et al., 2002). Overall, digestibility of dry and organic matter in this study was low for most fodder samples as supported by Sutardi 1980, who reported that digestibility is high at 70% or more, and low if the value is less than 50%. Under this study, *Capparis decidua, Acacia nilotica, Acacia mellifera, Calligonum polygonoides, Euphobia tirucali, Acacia brevispica, Cordia quercifolia and Kleinia spp* had organic matter digestibility (OMD) above 50% whereas dry matter digestibility (DMD) was below 50% except for *Acacia nilotica* that had 62.80%. The DMD for samples in this study was similar with OMD as increase in DM content is proportional to increase of OM content which is a component of DM. Hence, organic matter is part of dry matter and decreasing of dry matter will be followed by decreasing of organic matter (Sakinah, 2005).

5. Conclusion

Chemical composition characteristics of the browse species were moderate to high in their nutritional quality. Most sample forages had low total gas production and degradation rates. Hence most of the forages fed on by the camels are not easily degraded and absorbed. Only six samples were readily degraded, fermented, absorbed and utilized for body maintenance and production *(Haloxylon salicornicum, Acacia mellifera, Euphobia tirucali, Calligonum polygonoides, Capparis decidua* and *Indigofera spp*) with a range of 70.43 – 50.53ml/200mg). All the other thirteen samples were below 50ml/200mg. Differences in CP content of the forages under this study could have resulted due to difference in stage of growth and also proportion of mature foliage and twigs in the sampled species. Normally, fibre content is inversely proportional to CP as a plant matures.

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Authors contributions

Study conceptualization: Cyrila Lusala, Levi Musalia, James Kirimi and Florence Thiakunu. Data collection and sample preparation: Cyrila Lusala, Levi Musalia and James Kirimi. Study design and revising: Levi Musalia, James Kirimi, Cyrila Lusala and Florence Thiakunu. Drafting of the manuscript: Cyrila Lusala, Levi Musalia and James Kirimi. All authors read and approved the final manuscript. In addition, all authors contributed equally to the study.

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Competing interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Informed consent

Obtained.

Ethics approval

The Publication Ethics Committee of the Canadian Center of Science and Education.

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Data availability statement

The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

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No additional data are available.

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