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Effects of Supplementing Cowpea (*Vigna unguiculata*) Seed Hulls and Commercial Concentrate on Grazing Weanling Boer-Goats

Research Article

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ABSTRACT

The objective of the study was to evaluate chemical composition, *in vitro* dry matter digestibility (IVDMD), and growth performance of weanling Boer-goats supplemented with cowpea seed hulls (CSH) and commercial concentrate / feed (CF) with natural pasture as basal diet. Weanling Boer-goats (n=36) were assigned to 3 treatments comprising of 4 animals each (2 bucklings and 2 females) replicated three times in a completely randomized design (CRD) matrix. The goats aged between 12 and 18 months with initial body mass ranging from 17.5 - 38 kg (Mean±SD; 26.32±6.36). They were fed in a 42 d period as follows: diet 1 was the non-supplemented natural browse / pasture (control), diet 2 was the natural browse/pasture supplemented with commercial concentrate and diet 3 was the natural browse / pasture supplemented with cowpea seed hulls. Each of the supplemented diets was fed at the rate of 300 g per goat per day at 08:30 a.m. before goats could be released to graze/browse on the natural pasture within the paddock. Goats that grazed / browsed natural pasture alone (control) lost average weight of 1.12 kg, while goats that grazed / browsed natural pasture and supplemented with commercial concentrate gained 4.74 kg. Lastly, goats on basal diet and supplemented with cowpea seed hulls had average weight gain of 0.58 kg. Cowpea seed hulls can provide adequate protein and energy levels to sustain goat production during the extended dry season. The weight gain maintained during the dry season could easily upsurge when the conditions normalize after the first rains, hence early conception rate of goats.

KEY WORDS commercial concentrate / feed, cowpea (*Vigna unguiculata*) seed hulls, goats (*Capra aegagrus hircus*), natural pasture.

INTRODUCTION

Botswana's small stock production is described as either static or slowly growing (MoA, 2008) with a population of goats (*Capra aegagrus hircus*) estimated at 1.9 million and for sheep (*Ovis aries*) slightly over 279237 (Statistics Botswana, 2012). Most of the small stock is kept in communal areas in small flocks of 10-40 animals / household (MoA, 2012); sheep and goats contribute quite significantly to resource-poor persons both in terms of nutrition and income (MoA, 2012). There are a number of factors that contribute to slow growth of the small stock ranging from feed deficits, debilitating effects by internal parasites and death due to hypothermia, especially for kids and lambs born during winter months (MoA, 2012). Small stock in Botswana relies on the natural feed resources, which have evidently declined. The problem of low productivity of the rangeland is due to poor nutritive value that is characterised by high crude fibre (CF), low crude protein (CP), poor dry matter (DM) digestibility and low calcium (Ca) and phosphorus (P) contents, especially during the dry seasons (Mosimanyana and Kilflewahid, 1985; MoA, 2012). The protein content of grasses in Botswana is below 6% during the dry seasons (APRU, 1975; MoA, 2012) and there would be little or no browses at all. The government very often subsidizes purchases of feeds, veterinary requisites, and a selected number of vitamin supplements during the drought periods only to cattle. There is annual deficit of livestock feeds that is estimated at over 900000 tons (Mosimanyana and Kilflewahid, 1985; MoA, 2012). The alternate livestock feed in the tropics and subtropics is the non-conventional feedstuffs, which many researchers have opined to be too costly since the feed is also consumed by human beings and serves as raw materials for agro-processing industries (Adebiyi *et al*. 2010). In Botswana, a lot of crop residues are not sufficiently utilised as livestock feed even during drought years when the cultivated crops had failed to grow optimally. For example, the failed cowpeas (*Vigna unguiculata*) that would have been cultivated, their residues (including seed hulls) are either buried or burnt to avoid being spread by drafts without considering them as feed for small stock. Cowpea seed hulls could maintain live-weight gain of goats since they contain 15% crude protein (Falaye *et al.* 2012), which is within recommended maintenance values between 8.9% and 16% CP (NRC, 1981; Nuru, 1985). It has been proved that animals that do not maintain weight during the dry seasons have low conception rate in the subsequent breeding season (Roche, 2006). The present study was undertaken to compare the effects of supplementing commercial concentrate and cowpea seed hulls on grazing weanling Boer-goats.

MATERIALS AND METHODS

Study site and climatic conditions

The study was conducted at the Mantshwabisi Government ranch, located about 95 km from Gaborone (Capital City) in the north-eastern Kweneng District, Botswana. The climate of the area is classified as hot and semi-arid with mean daily temperature of 30 ˚C; mean rainfall of 153.4 mm per annum, which is received in summer months (December-April) (Meteorology, 2013).

The geographic position of the ranch is between the coordinates: S 24 ˚10' 47.4" and E 25 ˚16' 36.1" at an altitude of 1174 m above sea level. The capacity of the ranch is estimated at 430 hectares and subdivided into four paddocks with mean capacity of 86 hectares each. The vegetation of the ranch is woody or savannah grassland with plenty of *Acacia* Mill, *Terminalia*, *Grewia*, species and a variety of grass species such as *Digitaria* Haller, *Stipagrostis* Nees, etc.

Range assessment

The double sampling method was used in the estimation of forage production in a 97.2 hectare paddock (Bonham, 1989).

The paddock was divided into seven transects (500 m each) on which a 0.25 m^2 quadrat was thrown in every 10 metres (making a total of 50 transects) of a walking distance in an attempt to estimate cover which was partially or fully covered by either the vegetation as a whole or a single species.

In these small estimated plots the vegetation was independently clipped and weighed. Herbage weight drawn from the quadrats was multiplied by allowable factor (0.5) to obtain kg/ha of biomass as suggested by Hussain and Durrani (2009). From the small samples, the relation between estimated and actual dried weight was calculated and used to adjust the estimate of the large samples (Plastis and Papanastasis, 2003).

A total of 60 samples were randomly taken for measuring forage production. In an effort to determine the number of quadrats required in estimating standing crop forage production within 10 g and 20 g per quadrat of the population mean at 90 percent probability level, the quadrat weight (total of grazeable dry matter) was taken as a sample unit. The sample mean and standard deviation for different quadrat weights were calculated from the data.

Feed samples and samples origins

Dried samples of cowpea seed hulls, six different natural forages and commercial feed were collected from Kgatleng ploughing fields, Mantshwabisi ranch and local commercial supplier, respectively. These samples were milled through 1 mm screen after having been oven-dried at 65 ˚C for 24 h.

Chemical analyses

The dry matter (DM) was determined by drying the samples at 65 ˚C for 24 h and ash obtained by igniting the samples in a muffle furnace at 550 ˚C for 6 hours. Nitrogen content was measured by the Kjeldahl method (AOAC, 1990) and crude protein calculated as N × 6.25. Acid detergent fibre (ADF), neutral detergent fibre (NDF), acid detergent lignin (ADL) and ether extract (EE) content of the forage/feeds were determined using the method of Van Soest *et al.* (1991).

In vitro gas production study

Rumen fluid was obtained from three female Tswana-goats. The method used for the rumen liquor collection was as described by Fievez *et al.* (2005) and rumen liquor was from goats previously fed 60% hay-Lucerne and 40% concentrate at 3% body weight. The rumen fluid was collected into a thermo flask that had been pre-warmed to a temperature of 39 ˚C before morning feeding. The incubation procedure was as reported by Menke and Steingass (1988), using 120 mL calibrated transparent glass tubes fitted with needles at the bottoms.

Sample weighing 0.2 g (n=3) was put on the tubes and 30 mL of inoculums of strained rumen liquor and buffer (g/L) of 9.8 ($NaHCO_3$+2.22 Na_2HPO_4+0.57 KCl+0.47 NaCl+2.16 $MgSO_3$+$7H_2$) + 16 $CaCl_2.2H_2O$ was used. Incubation was carried out at 39 ˚C, and the gas volumes were measured at 2, 4, 8, 20, 24… and 48 hours. Gas production was not recorded after 48 h because of the concentrate characteristics of the experimental diets (Wallace *et al.* 2001). Due to failure to secure appropriate equipment used to quantify methane from trapped gas, a regression equation of methane production (mL/200 mg)= (0.032×CP) - (0.057×EE) - (0.012×CF) + (0.124×NFE) by Lee *et al.* (2003) was used to estimate methane production by each feed sample. Such parameters as metabolizable energy (ME), organic matter digestibility (OMD) and short chain fatty acids (SCFA) were estimated at 48 h post gas collection as according to Menke and Steingass (1988). The average volume of gas produced from the blanks was deducted from the volume of gas produced per sample. After 48 h of digestion, the samples were transferred into test tubes and centrifuged for 1 h in order to obtain the residues which were filtered using Whitman No. 4 filter paper by gravity and the residues placed in an oven for drying at 65 ˚C for 24 h. The residues obtained were weighed and digestibility calculated using the equation showed below:

IVDMD (%)= (initial DM input-DM residue blank) × 100 / initial DM input

Metabolisable energy (ME) was calculated as ME= 2.20 + 0.136 GV + 0.0057 CP + 0.00029 EE (Menke and Steingass, 1988). Organic matter digestibility (OMD %) was determined as OMD= 14.88 + 0.889 GV + 0.45 CP + 0.651 XA (Menke and Steingass, 1988). Short chain fatty acids (SCFA) were assessed through the calculation of 0.0239 GV - 0.0601 (Getachew *et al.* 1999). Where GV, CP, CF and XA are total gas volume, crude protein, crude fibre and ash, respectively.

Experimental animals, feeding and management

A total of 36 Boer-goats aged 15 ± 3.1 months old with body weight (BW) 26.32 ± 6.36 kg and animals of different mixed sex were used in this study. The Boer-goats are found in the drier areas of Botswana in fairly large numbers and are known to occupy all the agro-pastoral ecotones. These goats are known to be adapted to arid and semi-arid areas and could survive drought by utilizing little browses (MoA, 2012). Natural pasture was mainly used as basal diet for all the goats. However, experimental goats were supplemented with either commercial feed or cowpea seed hulls at the rate of 300 g per goat before they were released to graze / browse. The control group only grazed / browsed the natural pasture. Furthermore, all the goats were given dicalcium phosphate × salt licks and fresh clean water on free choice basis. The experimental goats were also dewormed before the start of the experiment with Nalsacur anthelmintic (after 14 d of immunization with enterotoxaemia vaccine) at 2.5 mL per 10 kg BW. The goats were housed in sufficiently ventilated pens with concrete floors at night after grazing during the day. For the three different treatments, different ear tag colour codes were used for ease of identification of the goats. The colour code for the control was red, commercial supplement, was green and for cowpea seed hulls supplement, was yellow. The experiment was carried out by following Research Council guidelines approved by Ethical Committee on Animal Experimentation of the Botswana of Agriculture / University of Botswana, which is in compliance with the world animal welfare statute.

Experimental study design

Thirty-six Boer-goats were partitioned into live-weight groups of four animals (two males and two females), with three replicates for each treatment, and within a live-weight group, animals were assigned dietary treatment in a completely randomized design (CRD). The first group was grazed / browsed with no supplemental diet (control); the second group of goats was offered 1.2 kg of commercial feed at 08:30 h and then released to graze / browse the natural pasture; the third group of goats was also offered 1.2 kg of cowpea seed hulls also at 08:30 h and released to graze / browse the natural pasture. The study comprised of a 14-day preliminary period of feed adjustment which was started on 15 June to 29 June; the actual study trial started on 30 June and finished on 26 August, 2013.

Supplemental feed residues

Daily supplemental diets offered and refusals were recorded for each set of animals. All the animals were weighed at the start of the experiment and every 2-weeks thereafter using a suspended weighing scale following a night of fasting. Furthermore, the forage value of the ranch was ascertained through the range assessment that was carried out in the paddock on which the goats grazed/browsed. The weight gain by goats was inferred from both the range condition and / or combination of the supplemental feeds offered.

Collection and preservation of rumen liquor

About two hundred millimetres of rumen liquor was collected from each of the nine goats randomly selected after having been fed each of the three diets or diet combinations. The rumen liquor was collected within two hours of goats having been fed supplemental diets / or grazed / browsed natural pasture (Satter and Slyter, 1974). Samples of rumen fluid were drawn using a suction tube inserted through the oesophagus to the rumen (Babayemi and Bamikole, 2006). The fluid samples were then strained through four layers of cheesecloth and then preserved as described by Han *et al.* (1989), briefly in 250 mL Erlenmeyer flask and acidified with 25% metaphosphoric acid (1 part acid and 5 part rumen liquor). Then the flask was put in a freezer at -20 ˚C until analyses were done.

Determination of ph and ammonia-nitrogen concentrations in rumen fluid

The pH values were determined immediately after collection by the use of Corning electronic pH electrode. The ammonia-nitrogen concentration was also determined by direct distillation and titration using the UDK Kjedahl Automatic Distillation Unit.

Determination of total volatile fatty acids in rumen liquor

A small proportion (1 mL) of rumen liquor was placed into the cup of distillation whereupon 0.5 mL of 5% oxalic acid together with 0.5 mL of 10% potassium oxalate solutions was added. The mixture was distilled for three minutes. The distillate was collected and a few drops of phenolphthalein indicator were added. The distillate was further titrated with 0.01 N sodium hydroxide.

Statistical analysis

The dependent variables analysed were *in vitro* organic matter digestibility (IVOMD) and weight of the goats. Data were analyzed using the mixed procedures of the SAS (2008). Performance characteristics were analysed with initial body weight (BW) used as covariate in analyzing performance variables. Means were compared by Dunnette t-test in the general linear model (GLM) procedure. Differences among means with $P < 0.05$ were accepted as representing statistically significant differences. For the *in vitro* gas production experiment, data obtained were subjected to general linear model (GLM) procedure. Where significant differences occurred, the means were separated using least significant difference (LSD) of the SAS.

RESULTS AND DISCUSSION

Table 1 describes the six forage species that are available among other forages in the area of the study. The total dry matter (DM) of the selected forage species was 1646.6 kg per hectare.

This showed grazeable / browseable dry matter of 823.3 kg per hectare at 50 percent utilization level (0.5 allowable factors). The mean live-body weight of goats was 25 kg. The carrying capacity of the paddock on which goats were grazed/browsed was 1.3 hectares per livestock unit (1.3 ha / LSU).

Table 1 Grazeable / browseable dry matter production (kg ha^{-1}) by different forage species at the Mantshwabisi Government Ranch, Kweneng District of Botswana

Forage name	Dry matter production (kg/Ha)	Forage value*
Grewia retinervis Burret.	41.88±0.07	Good
Ochna pulchra Hook.	17.92±0.27	Good
Terminalia sericea Burch	34.58±2.01	Good
Digitaria eriantha Steud.	561.77±2.09	Intermediate
Digitaria velutina (Forskk.) P. Beauv.	393.47±3.00	Intermediate
Stipagrostis uniplumis (Licht.) De Winter	596.98±3.30	Fair
Total	1646.6±0.90	-

* Forage value based on goat preference according to Holechek *et al.* (2004).

Composition of the diets

Nutrient composition of both supplemental diets and the six selected goat forages are presented in Table 2. Among the diets fed goats, commercial feed had the highest crude protein followed by *Grewia retinervis* Burret., *Ochna pulchra* Hook., cowpea seed hulls and *Terminalia sericea* Burch., and the grasses (*Digitaria eriantha* Steud., *Digitaria velutina* (Forskk.) P. Beauv. and *Stipagrostis uniplumis* (Licht.) De Winter) had the lowest protein mean values. Lignin (ADL) content was the highest in grass species followed by browses, cowpea seed hulls and the commercial concentrate being the lowest. The dry matter (DM) content of the grass species was the highest followed by browses, cowpea seed hulls and commercial concentrate being the lowest.

The neutral detergent fibre (NDF) content of the grasses was the highest as compared to browses, cowpea seed hulls and commercial feed. In quantifying acid detergent fibre (ADF) content among the feeds, commercial concentrate proved to have the lowest mean value, followed by cowpea seed hulls, browses and the grasses with the highest mean value. Ether extract content was the highest for supplemental commercial concentrate followed by cowpea seed hulls, browses and the grasses had the lowest mean value.

Performance characteristics of Boer-goats

Mean performance of Boer-goats on natural pasture (browse/graze), natural pasture supplemented with either commercial concentrate or cowpea seed hulls are presented in Table 3 and Figure 1. Initial body weights of goats on natural pasture were similar ($P>0.001$); however, goats on natural pasture supplemented with commercial concentrate gained the highest (4.74 kg; $P<0.05$) followed by goats grazed / browsed on natural pasture and supplemented with cowpea seed hulls (0.58 kg).

Table 2 chemical compositions (g/100 grams dry matter) of cowpea seed hulls, commercial feed / concentrate and natural forages fed goats at the Mantshwabisi Government Ranch, Kweneng District of Botswana

Forage / feed	DM	CP	EE	ASH	NDF	ADF	ADL	NFE
Cowpea seed hull	93.70^{d}	6.50^{d}	3.59^{b}	8.89^{c}	47.31^{bc}	37.23^{f}	35.03^{d}	34.53^{f}
Commercial feed	92.20^{e}	12.52^{a}	5.11^{a}	22.4^{a}	45.04^{c}	10.40^{h}	7.96^{f}	31.13^{g}
Grewia retinervis Burret.	93.75^{cd}	9.13^{b}	0.59^{d}	5.50^{ef}	22.53^{d}	32.33^{g}	28.60^{e}	52.07^{a}
Digitaria eriantha Steud.	95.39^{a}	3.64^{e}	0.11^{g}	6.33^{d}	48.55^{ab}	46.00d	39.80^{c}	39.33^{c}
Digitaria velutina (Forskk.) P. Beauv.	95.35^{a}	2.41^{f}	0.60^{d}	15.0^{b}	51.29^{a}	46.89^{c}	43.00^{b}	29.60^{h}
Ochna pulchra Hook.	94.71^{b}	7.40^{c}	0.50^{e}	4.57^{de}	47.7^{bc}	48.00^{b}	38.77^{c}	36.90^{e}
Terminalia sericea Burch.	94.32^{bc}	6.55^{d}	0.81^{c}	4.40^{e}	48.54^{ab}	39.17^{e}	27.40^{e}	43.50^{b}
Stipagrostis uniplumis (Licht.) De Winter	94.91^{ab}	2.84^{f}	0.29^{f}	4.93^{de}	49.25^{ab}	49.47^{a}	47.87^{a}	37.90^{d}
Mean	94.29	6.37	1.45	9.00	45.03	38.68	33.55	38.20
SEM	0.22	0.67	0.3 6	1.27	1.84	2.52	2.43	1.41

DM: dry matter; CP: crude protein; EE: ether extract; NDF: neutral detergent fibre; ADF: acid detergent fibre; ADL: acid detergent lignin and NFE: nitrogen free extract= (100-moisture+ash+CP+CF+EE).
SEM: standard error of means.
The means within the same column with at least one common letter, do not have significant difference (P>0.05).
* Protein analysis is on dry matter basis.

Table 3 Performance characteristics of Boer-goats grazed / browsed natural pasture and grazed / browsed natural pasture supplemented with either commercial concentrate or cowpea seed hulls at the Mantshwabisi Government Ranch, Kweneng District of Botswana

Variables	NP × CF	NP × CSH	NP
No. of goats	12	12	12
Initial body weight (kg)	27.0^{a}	24.5^{ab}	27.5^{a}
Final body weight (kg)	31.74^{a}	25.08^{b}	26.38^{b}
Total gain (kg)	4.74^{a}	0.58^{b}	-1.12^{b}
Average daily gain (g/day)	79.0^{a}	9.7^{b}	-18.7^{b}

NP × CF: natural pasture supplemented with commercial feed; NP × CSH: natural pasture supplemented with cowpea seed hulls and NP: natural pasture alone.
The means within the same row with at least one common letter, do not have significant difference (P>0.05).

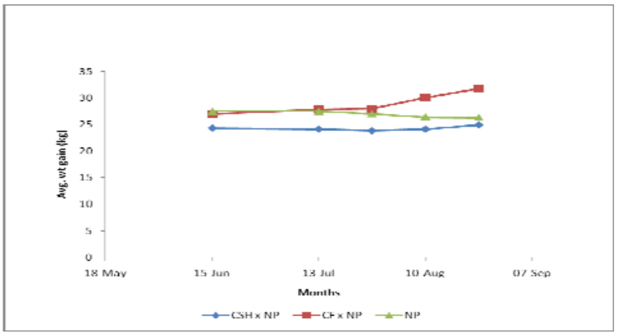

Figure 1 Total effects of grazing Boer-goats supplemented with either commercial concentrate or cowpea seed hulls on weight gain at the Mantshwabisi Government Ranch, Botswana
Key: CSH × NP: natural pasture supplemented with cowpea seed hulls; CF × NP: natural pasture supplemented with commercial feed and NP: natural pasture unsupplemented

There was, however, no significant difference (P>0.05) between the Boer-goats grazed / browsed natural pasture and supplemented with cowpea seed hulls and those grazed / browsed natural pasture alone.

Comparison of performance of intact male and female goats

Table 4 and Figures (3 and 4) describes the performance results of intact male Boer-goats and female Boer-goats grazed / browsed natural pasture alone and Boer-goats grazed / browsed natural pasture supplemented with either commercial concentrate or cowpea seed hulls. The initial mean body weights of intact males fed control diets and natural pasture supplemented with commercial concentrate were higher (P>0.05) compared to their female counterparts fed similar diets. Furthermore, the initial mean body weights of intact male goats grazed / browsed natural pasture and supplemented with cowpea seed hulls were lower (P<0.05) than those for their female counterparts fed similar diets. By the end of the study, intact males grazed/browsed and supplemented with commercial concentrate had gained mean BW 4.1 kg while females gained mean BW 5.4 kg. Also, the mean BW gains by intact male goats fed basal diet and basal diet supplemented with cowpea seed hulls were not significantly different (P>0.05) from their female counterparts, respectively.

In vitro gas production characteristics

Figure 4 shows the *in vitro* gas production characteristics by commercial feed, cowpea seed hulls, natural browses and grasses. There were varied rates of increase in the gas production in the first 6h. Among the goats' diets at 48 h, *Stipagrostis uniplumis* (Licht.) De Winter had the lowest gas production followed by *Digitaria velutina* (Forskk.) P. Beauv., *Digitaria eriantha* Steud., *Ochna pulchra* Hook., *Grewia retinervis* Burret., *Cowpea seed hulls*, *Terminalia sericea* Burch. and commercial feed being the highest. Furthermore, the lowest and the highest values for metabolizable energy (MJ/kg DM), organic matter digestibility (%), methane (mL/200 mg), short chain fatty acids (µmmol) and *in vitro* dry matter digestibility (IVDMD) (%) ranged from 2.8 in *Stipagrostis unimplumis* Nees. to 5.2 in commercial feed; 23.3 in *Stipagrostis uniplumis* Nees. to 54.6 in commercial concentrate; 3.2 in *Digitaria velutina* (Forskk.) P. Beauv.to 6.4 in *Grewia retinervis* Burret.; 0.37 in *Stipagrostis uniplumis* Nees. to 0.78 in commercial feed; 44.7 in *Stipagrostis uniplumis* Nees. to 79.6 in commercial feed, respectively (Table 5).

Table 4 Comparison of performance of intact male and female goats fed natural pasture and natural pasture supplemented with either cowpea seed hulls or commercial concentrate at the Mantshwabisi Government Ranch, Kweneng District of Botswana

Parameter	Intact male goats ±SD			Female goats ±SD		
	NP	NP × CF	NP × CSH	NP	NP × CF	NP × CSH
Initial BW (kg)	28.8±5.9[a]	29.2±5.1[a]	23.0±2.5[c]	26.2±6.3[b]	24.8±7.5[c]	25.7±7.2[b]
Final BW (kg)	26.9±4.6[c]	33.3±8.4[a]	23.6±1.8[c]	25.8±6.8[c]	30.2±7.2[b]	26.3±7.0[c]
Daily gain(g/d)	-31.7±1.3[c]	68.3±3.3[b]	10.0±0.7[c]	-6.7±0.5[c]	90.0±0.3[a]	10.0±0.2[c]

NP × CF: natural pasture supplemented with commercial feed; NP × CSH: natural pasture supplemented with cowpea seed hulls and NP: natural pasture alone.
The means within the same row with at least one common letter, do not have significant difference (P>0.05).
SD: standard deviation.

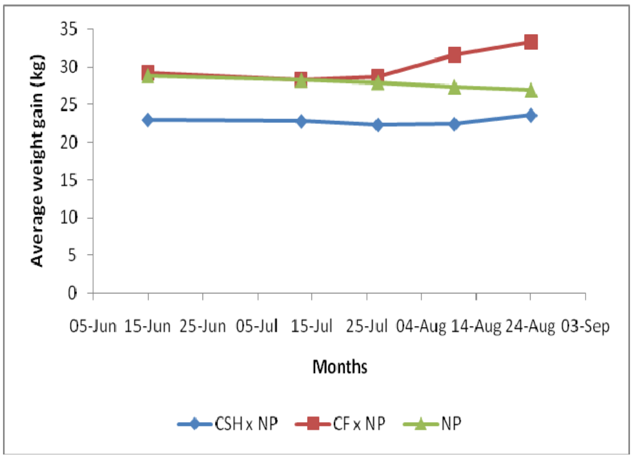

Figure 2 Effects of grazing intact male Boer-goats supplemented with either commercial concentrate or cowpea seed hulls on weight gain at the Mantshwabisi Government Ranch, Botswana
Key: CSH × NP: natural pasture supplemented with cowpea seed hulls; CF × NP: natural pasture supplemented with commercial feed and NP: natural pasture unsupplemented

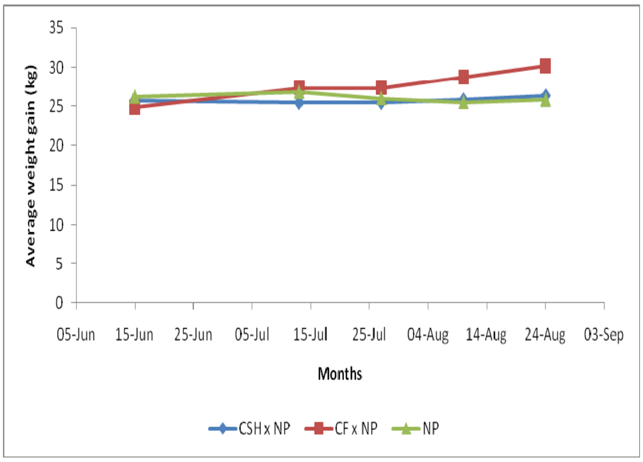

Figure 3 Effects of grazing female Boer-goats supplemented with either commercial feed or cowpea seed hulls on weight gain at the Mantshwabisi Government Ranch, Botswana
Key: CSH × NP: natural pasture supplemented with cowpea seed hulls; CF × NP: natural pasture supplemented with commercial feed and NP: natural pasture unsupplemented

Rumen liquor pH

Table 6 shows comparison of rumen pH and ammonia-nitrogen production after goats were fed different diets.

The mean pH of rumen liquor for goats fed natural pasture (control) was the highest (P<0.05) followed by the cowpea seed hulls supplemented goats and the lowest being for commercial concentrate supplemented goats.

Rumen liquor ammonia-nitrogen

The ammonia-nitrogen concentration in rumen liquor of the goats supplemented with commercial concentrate was the highest (P>0.05) followed by goats fed natural pasture supplemented with cowpea seed hulls and goats grazed / browsed only (Table 6). However, there was no significant difference (P>0.05) between the ammonia-nitrogen concentration obtained from goats fed natural pasture and the goats fed natural pasture and supplemented with cowpea seed hulls. The mean concentration of ammonia-nitrogen increased correspondingly with increasing level of crude protein content of the supplemental diets. The ammonia-nitrogen concentrations for goats on natural pasture supplemented with commercial concentrate, natural pasture supplemented with cowpea seed hulls and natural pasture with no supplement were 120, 104 and 97 mg/L, respectively.

Total volatile fatty acids concentration (TVFA)

The rumen liquor for goats grazed / browsed on natural forage showed the highest total volatile fatty acid concentrations followed by commercial feed × natural forage and cowpea seed hulls × natural forage (Table 6). However, there were no significant differences (P>0.05) in the production of volatile fatty acids among the goats fed different diets or diet combinations. The total grazeable/browseable dry matter (DM) for the paddock was determined as 1646.6 kg per hectare. Holechek *et al.* (2004) reported that daily dry matter intake of moose, bighorn sheep, mule deer, white tailed deer, elk and pronghorn antelopes as two percent of their body weight. Since the DM intake for the goats at the Mantshwabisi Government ranch was not worked out, therefore DM intake was taken as two percent of their live-body weight as suggested by Holechek *et al.* (2004).

However, the total number of goats grazed / browsed in this study stood at thirty-six. This shows that the paddock had ample pasture to support extra 402 goats.

Table 5 Net gas volume, methane, metabolizable energy, organic matter digestibility, short chain fatty acids and *in vitro* dry matter digestibility of goat's feeds at the Mantshwabisi Government Ranch, Kweneng District of Botswana

Feed / forage	NGV	CH_4	ME	OMD	SCFA	IVDMD
Cowpea seed hull	11.48^{c}	3.80^{f}	3.80	33.82^{ab}	0.54	62.10^{c}
Commercial feed	21.81^{a}	3.68^{g}	5.24	54.56^{a}	0.78	79.85^{a}
Grewia retinervis Burret.	10.81^{d}	6.37^{a}	3.73	32.19^{ab}	0.52	60.70^{c}
Digitaria eriantha Steud.	5.14^{f}	4.53^{c}	3.11	26.38^{b}	0.42	50.63^{e}
Digitaria velutina (Forskk.) P. Beauv.	5.20^{g}	3.21^{h}	2.92	30.32^{b}	0.39	47.53^{f}
Ochna pulchra Hook.	10.5^{e}	4.31^{d}	3.67	30.54^{b}	0.51	57.90^{d}
Terminalia sericea Burch.	17.15^{b}	5.11^{b}	4.57	35.98^{ab}	0.67	66.10^{b}
Stipagrost.uniplumis (Licht.) De Winter	4.46^{h}	4.20^{e}	2.83	23.33^{b}	0.37	44,70^{h}
Mean	10.98	4.40	3.73^{ns}	33.39	0.53^{ns}	58.69
SEM	1.17	0.19	0.38	2.93	0.07	2.22

NGV: net gas volume (mL/200 mg DM); CH_4: methane (mL/200 mg DM); ME: metabolizable energy (ME=MJ.kg^{-1} DM); OMD: organic matter digestibility (OMD=%); SCFA: short chain fatty acid (µmmol) of goats feeds / forages and IVDMD: *in vitro* dry matter digestibility.
SEM: standard error of means.
NS: non significant.
The means within the same column with at least one common letter, do not have significant difference (P>0.05).

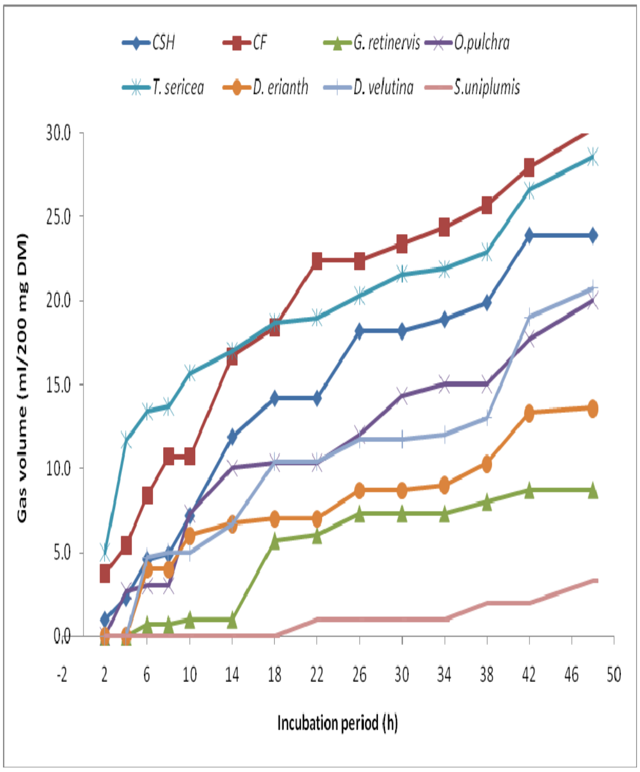

Figure 4 *In vitro* gas production by commercial feed, cowpea seed hulls, natural browses and grasses at the Mantshwabisi Government Ranch, Botswana
Key: CSH: cowpea seed hulls; CF: commercial feed / concentrate; *Grewia retinervis* Burret.; *Ochna pulchra* Hook.; *Terminalia sericea* Burch.; *Digitaria erianth* Steud.; *Digitaria velutina* (Forskk.) P. Beauv.; *Stipagrostis uniplumis* (Licht.) De Winter

The crude protein (CP) content of diets used in this study was below the CP (12.9%-24.4%) of forage reported from west Africa (Rittner and Reed, 1992). However, most of the browse forages / feeds had CP content above 6% while for the grasses mean CP content was about 3%.

The results of this study indicate that most of the browse species have sufficient CP to stimulate effective microbial synthesis in the rumen.

The non-woody parts of the browses have greater quantities of cell solubles than the monocots (grasses) and lower levels of structural carbohydrate and lignin. However, this apparent advantage in the browses is often compromised by some biologically significant proportions such as tannins, volatile oils and alkaloids which have deleterious effects on the microbial fermentation (Hegarty, 1982).

Conversely, grasses have lower crude protein content which often results in loss of weight by goats during the dry seasons (MoA, 2012). Forage species that have crude protein lower than 6% do not support rumen microbial synthesis (Ørskov and Ryle, 1990). Obviously, these grasses take longer period to be degraded in the rumen and with that reducing intake by animals, hence their loss of weight. The nutritive status of these grasses exemplifies the characteristic nature of the C_4 grasses as they contain less mesophyll and greater proportions of *sclerenchyma*, epidermis and vascular tissue.

The vascular bundles found in monocotyledones grasses are often densely packed and the *parenchyma* bundle sheaths are thick-walled denoting high neutral detergent fibre and as such inhibiting microbial digestion in the rumen (Huston *et al*. 1986).

The mean daily live body weight gain and mean final body weight obtained in the present study was higher (P>0.05) for the goats grazed / browsed natural pasture and supplemented with commercial concentrate compared to the goats supplemented with either cowpea seed hulls and / or the control treatment (Figure 1).

The final weight gain of the goats grazed and supplemented with cowpea seed hulls was not statistically significant (P>0.05) from goats fed basal diet (control). The low weight gain for the goats supplemented with cowpea seed hulls may be partly attributed to feed refusal by the goats when the supplemental feed was first introduced. The goats took about seven days without feeding on the introduced supplement (cowpea seed hulls).

The goats were therefore kept in pens with the supplemental diet and plenty of clean water while the other groups of goats were fed their respective treatments as planned. Apparently, when the goats started feeding on the cowpea seed hulls they had already lost some weight.

Table 6 Rumen fluid measurements from natural pasture-fed, natural pasture-fed plus commercial feed and natural pasture-fed plus cowpea seed hulls supplemented weanling Boer-goats at the Mantshwabisi Government Ranch, Kweneng District of Botswana

Attribute	NP	NP × CF	NP × CSH
Animals used	3	3	3
Rumen fluid pH	6.94 0.17^{a}	6.34 $\pm 0.06^{c}$	6.70 ± 0.33^{b}
NH_3-N produced	97^{b}	120^{a}	104^{b}
Within 2 h (NH_3/100 mL of rumen fluid)			
- -		TVA (mEq/L)	
- -	50	49.2	46.3^{ns}

NP: natural pasture (grass and browses) alone; NP × CF: natural pasture supplemented with commercial feed; NP × CSH: natural pasture supplemented with cowpea seed hulls; TVFA: total volatile fatty acids and mEq/L: mill equivalent per litre.
NS: non significant.
The means within the same row with at least one common letter, do not have significant difference (P>0.05).

On the other hand, the weight loss from the goats that grazed basal diet (control) alone could be due to less nutrient density extracted from the basal diet that did not meet the daily requirements of the animals (Mosimanyana and Kilflewahid, 1985; MoA, 2012). The mean crude protein (5.3%) of the browsed forage was lower than the appreciable extractive crude protein (6-8%) by the rumen microbes (Huston *et al.* 1986). This corroborates McDonald *et al.* (2002), that feeds which have lower than 6% crude protein do not support microbial activity in the rumen and consequently limit the rate of digestion in the rumen. Devendra and McLeroy (1982) also reported that it was important for animals fed fibrous diets to be supplemented with feeds rich in crude protein.

The mean pH values for the rumen liquor of goats fed natural pasture and natural pasture with supplemental combinations were slightly lower than the pH values described in a similar study elsewhere (Islam, 1999). The ARC (1984) reported that the most nutritionally desirable diets should have pH of 7.32, which was never the case with the current findings. The least pH value for the rumen liquor obtained from the goats fed natural pasture supplemented with commercial concentrate could be due to the lower physically effective neutral detergent fibre (*pe*NDF) of the supplemental diet. Ruminant feeds with lower physically effective NDF have the problem of stimulating low production of saliva which could otherwise increase the buffering process (Mirzaei-Aghsaghali and Maheri-Sis, 2011).

Physically effective neutral detergent fibre (*pe*NDF) of a feed is related to the physical properties of its fibre content (primarily particle size) that stimulates chewing activity and establishes biphasic stratification of ruminal contents (Mirzaei-Aghsaghali and Maheri-Sis, 2011). The commercial concentrate was observed to have smaller particles than for cowpea seed hulls. The suggestion of smaller particle size of feed leading to lowered ruminal pH was also reported by Ørskov and Ryle (1990), who said that pelleted roughage (higher *pe*-NDF) could show a lowered pH value than coarse roughage. Slightly higher pH in both the natural pasture and natural pasture x cowpea seed hulls fed goats might be due to effective neutral detergent fibre (*pe*-NDF) (effective chewing and ruminal activity) content of the forage consumed. The cowpea seed hulls and the natural pasture forage parts were much elongated although less coarse. The overall observation of the rumen liquor mean pH values from the goats were maintained at a higher level than the critical level of the rumen pH (6.0) for fibre digestion (Ørskov and Ryle, 1990). The cellulolytic microbes need a rumen pH between 6.2 and 7.0 (Ørskov and Ryle, 1990), and in the current study, the pH values for rumen liquor of goats fed either sole natural pasture or natural pasture with supplemental diets ranged from 6.34 to 6.94.

The ammonia-nitrogen concentration of rumen fluid from goats fed natural pasture supplemented with commercial concentrate was significantly higher (P<0.05) than for either goats fed basal diet or basal diet supplemented with cowpea seed hulls. Although the ammonia-nitrogen concentrations in goats fed either natural pasture alone or natural pasture supplemented with cowpea seed hulls were relatively low, they were both above the critical (50 mg/L) level (Preston, 1986; Leng, 1990). The critical level of ammonia-nitrogen concentration is that level which might affect fibre digestion of a feed (Ørskov and Ryle, 1990).

Ammonia-nitrogen concentration levels for better digestion have been speculated by different workers: some estimated to be within 50-70 mg/L (Satter and Slyter, 1974) while others said it should be in the range of 150 to 200 mg/L (Krebs and Leng, 1984; Preston, 1986). However, Boniface *et al.* (1986) reported that for optimal rumen performance, the ammonia-nitrogen concentration should be within a range of 45 to 120 mg/L. The amount of ammonia-nitrogen reported in the present study was higher than that reported by Satter and Slyter (1974), but lower than those reported by Krebs and Leng (1984) and Preston (1986), but within the ranges reported by Boniface *et al.* (1986).

Islam *et al.* (1999) hypothesised that for most fibrous diets, the major limiting factor for the growth of microbes is due to low ammonia-nitrogen concentrations. For ammonia-nitrogen concentration to support microbial synthesis it has to be above the critical level for a considerable period of the day after feeding (Satter and Slyter, 1974). The deficiency of ammonia-nitrogen could result in the reduction of microbial populations (Satter and Slyter, 1974). Ørskov and Ryle (1990) also reported that the decrease in microbial synthesis affects feed intake of ruminant animals. The ammonia-nitrogen concentrations observed from the dietary treatments were within 2 h of sampling; the lower results of ammonia-nitrogen concentrations obtained were possibly suggestive of the immediate effects of feeding.

The mean weight gain of female goats was higher (P<0.05) than that of the intact males fed corresponding diets or diet combinations. This suggested that the female weanlings were at their fastest growing period compared to intact males. The values for body gain in the present study were in agreement with those reported by Gubartella *et al.* (2002) for grazing male (56 g/day) and female (80 g/day) Nubian weanling goats. If the study was to be continued further, intact male weanlings might have gained more weight than the females due to the effect of testosterone. Testosterone increases efficiency of dietary nitrogen utilization (Garray, 2005) and muscle protein accretion in intact male animals (Morgan *et al.* 1993).

Total volatile fatty acid (TVFA) concentration in ruminal liquor of the goats in this study was higher than the TVFA (27.9 mEq/L) concentrations reported by Antoniou and Hadjipanayiotou (1985) and Fondevilla *et al.* (1994) in grazing goats and sheep. High total volatile fatty acid concentrations indicate protein degradability (Orskov and Ryle, 1990). Forages / feed in this study may have provided sufficient energy and nitrogen for the fibrolytic microorganisms (Huston *et al.* 1986). The volatile fatty acids (acetate, propionate and butyrate) play a major role during fermentation in the rumen and they are metabolized through a network of pathways into the bloodstream; when they finally yield carbon dioxide and water, high powered energy bonds are captured in the form of ATP (Huston *et al.* 1986).

The values of metabolizable energy (ME), organic matter digestibility (OMD) and short chain fatty acids (SCFA) obtained in the current study were higher than those reported on tropical forages (Njidda and Ikhimioya, 2010). There are many variables that can influence metabolizable energy, organic matter digestibility and short chain fatty acids production in the feed ingredients such as anti-nutritional factors, the presence or absence of prebiotics (fermentable dietary carbohydrates) and the probiotics (rumen bacteria) (Lee *et al.* 2003). The improvements observed in the apparent digestibility of the diets may be due to better nutrient profile and higher solubility of carbohydrates, however, OMD improved with increasing levels of CP in the diets (Table 2).

The correlation (r=0.999; P<0.0001) between *in vitro* gas productions measured after 48 h incubation of cowpea seed hulls, commercial concentrate, browses, grasses and calculated short chain fatty acids was consistent with reports elsewhere (Blummel *et al.* 1999; Njidda and Ikhimioya, 2010).

Among the feed treatments, commercial concentrate, cowpea seed hulls and browses had high organic matter digestibility effects (MSU, 2010). This is in agreement with Gazaneo *et al.* (2003) and it might be due to the microbes having degraded the easily fermentable carbohydrates of the feeds. Gas production increased with organic matter digestibility. Based on the latter parameter the eight feeds could be ranked as follows: Su (23%) < De (26%) < Dv (30%) < Op (31%) < Gr (32%) < CSH (34%) < Ts (36) < CF (55%).

There were no differences (P>0.05) in SCFA among the feedstuffs. The gas production in feeds was closely related to the production of short chain fatty acids, which were also based on carbohydrate fermentation (Blummel and Ørskov, 1994). Gas volumes produced in the study were produced quantitatively and qualitatively as a result of SCFA production (the amount of fermentative CO_2 and CH_4 could be accurately calculated from the amount and proportion of acetate, proportionate and butyrate present in the incubation medium). Thus, the feedstuff increased in SCFA resulted in higher gas production that ultimately heightened digestibility and energetic value (Maheri-Sis *et al.* 2011). Although predicated metabolizable energy profile among feedstuffs showed variations in quantity, these were not statistically different.

As shown in the results (Table 4) *in vitro* dry matter digestibility of feedstuffs was the highest in the commercial concentrate. Commercial concentrate did not have leaves and possibly that was the reason why its digestibility was the highest. Leaves tend to have tannins in both the NDF and ADF fractions tightly bound to the cell wall and cell protein and they decrease digestibility (Reed *et al.* 1990). On the other hand, cowpea seed hulls were higher in dry matter digestibility compared to either grasses or browse forages. Forages with high dry matter content tend to have low tannin (Aganga *et al.* 1998). This probably suggested that the cowpea seed hulls had low tannins and as a result could be valuable protein supplement in ruminant diets (Aganga and Mosase, 2001). The acceptable character of this supplement was further manifested by its low methane production. Methane is known to be responsible for energy losses in ruminants especially in tropical forages orchestrated by methanogenic bacteria (Babayemi and Bamikole, 2006).

CONCLUSION

Chemical composition and *in vitro* digestibility can be useful indicators in evaluating the nutritive value of feeds, their organic matter digestibility (OMD), short chain fatty acids (SCFA) and metabolisable energy (ME). Cowpea seed hulls can provide adequate protein and energy levels to sustain goat production during the extended dry season as resource-poor farmers may not be able to purchase commercial feed. The cowpea seed hulls' advantage from natural pasture was further manifested in its dry matter digestibility (>60%) and low methane production. Nevertheless, commercial concentrate showed propensity for greater weight gain in goats, but it is not affordable to resource-poor farmers.

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