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Nutritive value of processed feed resources from natural pastures within South-West Nigeria

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Additional keywords

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Hay.
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SUMMARY

The nutritive value of forage resources from natural grazing land as dry season feed supplements for grazing animals was evaluated through their chemical composition and *in vitro* gas production. The forage resources include conserved forages (hay and silage), browse plant (*Leucaena leucocephala* leaves) and the forages in the natural pasture during the dry season served as the control. Crude protein (CP) contents of the forage resources ranged from 59 to 171 g/kg dry matter (DM), with *L. leucocephala* leaves having the highest ($p<0.05$) CP contents. Neutral detergent fibre (NDF) and acid detergent fibre (ADF) contents of the forage resources ranged from 560 to 705 g/kg DM and 363 to 440 g/kg DM, respectively. The highest in vitro gas production of 38.7 ml/200 mg DM was recorded for *L. leucocephala* leaves which was followed by silage and hay while forages in the natural pasture during the dry season recorded the least gas production. The volume of gas production significantly ($p<0.05$) ranged from 13.7 ml/200 mg DM in natural pasture to 38.7 ml/200 mg DM in *L. leucocephala* leaves. The fractional rate of gas production value of 0.10 h^{-1} was highest in *L. leucocephala* leaves and lowest in the silage with the value of 0.07 h^{-1}. *L. leucocephala* leaves had the highest ($p<0.05$) values of ME, OMD and SCFA (16.8 MJ/ kg DM, 64.7 % and 0.8 μmol respectively while natural pasture recorded lowest values of 5.3 MJ/kg DM, 32.8%, 0.2 μmol for ME, OMD and SCFA respectively. The study showed that conserved forages (hay and silage) and browse plant (*L. leucocephala* leaves) were superior to forage in natural pasture during dry season in terms of CP and gas production, thus indicating higher nutritive potential. They may therefore be used as supplements for ruminants that are grazing on poor quality roughages during the dry season.

Valor nutritivo de los recursos alimenticios procesados procedentes de pastos naturales en South-West Nigeria

Palabras clave adicionales

Ramoneo.
Heno.
Pastos naturales.
Ensilado.

RESUMEN

El valor nutritivo de recursos forrajeros de pastos naturales alimenticios en la estación seca para los animales en pastoreo fueron evaluados a partir de su composición química y producción de gas *in vitro*. Los recursos forrajeros incluyen forrajes conservados (henos y ensilado), planta arbustiva (hojas de *Leucaena leucocephala*) utilizando como control los forrajes del pasto natural durante la estación seca. El contenido de proteína bruta (CP) de los recursos forrajeros osciló de 59 a 171 g/k^{-1} de materia seca (DM), siendo las hojas de *L. leucocephala* las que presentaron el mayor ($p<0,05$) nivel de CP. Los contenidos de fibra neutro detergente (NDF) y fibra ácido detergente (ADF) de los recursos forrajeros oscilaron de 560 a 705 g/kg DM y de 363 a 440 g/kg DM respectivamente. La mayor producción de gas *in vitro* fue de 38,7 ml/200 mg DM, registrada en hojas de L. leucocephala seguidas del ensilado y heno mientras que los forrajes del pasto natural durante la estación seca registraron la mínima producción de gas. El volumen de producción de gas varió significativamente ($p<0,05$) de 13,7 ml/200 mg DM en el pasto natural a 38,7 ml/200 mg DM en las hojas de *L. leucocephala*. El valor de la tasa fraccionaria de producción de gas fue mayor en las hojas de *L. leucocephala* (0,10 h^{-1}) y menor en el ensilado con un valor de 0,07 h^{-1}. Las hojas de L. leucocephala presentaron los valores más altos ($p<0,05$) para ME, OMD y SCFA (16,8 MJ kg-1 DM, 64,7 % y 0,8 μmol respectivamente, mientras que los pastos naturales registraron los valores más bajos de 5,3 MJ kg^{-1} DM, 32,8 %, 0,2 μmol para ME, OMD y SCFA respectivamente. El estudio demostró que los forrajes conservados (heno y ensilado) y las hojas de la planta arbustiva *L. leucocephala* fueron los forrajes mejores en el pasto natural durante la estación seca en términos de CP y producción de gas indicando así mayor potencial nutritivo. Por eso pueden ser utilizadas como suplementos para rumiantes en pastoreo sobre forrajes de baja calidad durante la estación seca.

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INTRODUCTION

In the traditional animal husbandry, ruminants in the tropics especially Nigeria, are mainly fed grass. Improved livestock production is likely unattainable and unsustainable by grass forages alone. This is because grasses which constitute above 75 % of ration for ruminants are seasonal. In Nigeria, ruminants gain weight during the rainy season, and rapidly loose it in the dry season (Babayemi and Bamikole, 2006).

Forages have supplied the most economical feeds for ruminants and with the increasing price of grain feeds, forage has become much more important as a feed resource, since it cuts down feed cost, thereby reducing the total cost of animal production.

Tropical grasses grow and mature under a high temperature regime which stimulates growth and aging of the plants with a consequent decrease in nutrients and digestibility (Atta-Krah and Reynolds, 1989). Herbage availability during the wet season often exceeds animals' requirements in the natural pasture (Chakoma *et al.*, 1999). The accumulated forage rapidly declines in quality and quantity with increasing maturity. In order to solve this limitation of feeds for ruminants especially during the dry season, there is a need to develop feed conservation strategies, especially from natural grazing land by conserving the excess as hay and silage when their quality could still meet livestock requirement. This will make high quality forage available over the period of scarcity and prevent the loss in weight of animals associated with this period.

In addition bushes and plant trees are more drought tolerant than grasses, this is as a result of relatively deep roots of these woody perennials which allow them to reach soil nutrients and moisture not available to grasses and herbaceous plants. Moreover, browse plants are able to retain fresh foliage into the dry season which can be utilized in developing sustainable feeding systems (Woodward and Reed, 1989). The ability of some legume trees to fix atmospheric nitrogen makes them protein rich feeds.

Evaluating the nutritive value of forages makes an important contribution to the protein and energy intake of grazing animals (Cline *et al.*, 2010). This is particularly important in the regions where available forage and quality are limited during the dry season. Menke and Steingass (1988) developed the *in vitro* gas production technique to evaluate the nutritive value of forages and a method to estimate the rate and extent of DM degradation indirectly, using gas production data. This technique stimulates the digestive processes generated by microbial activity and helps to understand feed formulation and degradability as a function of nutritional quality and nutrient availability for the bacteria. The *in vitro* gas production has been widely used to estimate the nutritive quality of different classes of forages (Njidda, 2010). However, there is little information about *in vitro* gas production of forage resources from the natural pastures that can be fed to grazing animals during the dry season. The objective of this study was to determine the nutritive value by means of chemical composition and *in vitro* gas production of forage resources from natural pasture as dry season feed supplement for grazing ruminants in South Western Nigeria.

MATERIALS AND METHODS

Sample collection and preparation

This study was carried out at the Federal University of Agriculture, Abeokuta, Nigeria (FUNAAB). The site lies within the derived savannah agro-ecological zone of South-Western Nigeria (latitude 7°N, longitude 3.5°E, average annual rainfall 1.037 mm). Abeokuta has a bimodal rainfall pattern that typically peaks in July and September with a break of 2 to 3 weeks in August. Temperatures are fairly uniform with daytime values of 28– 30 °C during the early rainy season of the year (April–June) and late rainy season (July–September) and 30–34 °C during the early dry season (October–December) and late dry season (January–March) with the lowest night temperature of around 24 °C during the harmattan period between December and February. Relative humidity is high during the rainy season with values between 63 % and 96 % as compared to the dry season (55–84 %). The temperature of the soil ranges from 24.5 to 31.0 °C (source: Agrometeorology Department, FUNAAB).

Forage samples were harvested at about 5 cm above ground level during the late rainy season from specified natural grazing land within the University. The forage samples were sorted out and the proportion of each plant species in the composite were weighed and recorded as follows: for grass components, *Hyparrhenia rufa* (2.06 %), *Panicum maximum* (6.21 %), *Andropogon tectorum* (11.24 %), *Cynodon nlemfuensis* (2.12 %), *Andropogon gayanus* (17.82 %), *Pennisetum pedicellatum* (2.11 %) and *Pennisetum purpureum* (23.11 %), and the legume components were *Calopogonium mucunoides* (7.45 %), *Mucuna pruriens* (9.13 %) and *Tephrosia bracteolata* (18.75 %). These proportions were collected in three (3) replicates and used for the production of hay and silage. For silage production, the forages were chopped to <1.5 cm and wilted for 4 hours to reduce their moisture contents. The wilted forages were carefully packed into bunker silo measuring 8.5 x 5.3 x 1.8 m. This was compressed rapidly and compacted using a tractor to displace the air so as to initiate anaerobic fermentation. The stack was then covered with tarpaulin with used tyres and stones on top to ensure an airtight condition. The forages were ensiled for 90 days before opening and subsequent analyses.

Hay was made with the second portion of the forages by spreading on the floor for 2 days in the sun. Baling was done by placing rope in the baling chamber of the baler, filled with the dried forages, compressed and tied with the rope. The baled hays were stored in a cool, dry and airy store. Leaves of *Leucaena leucocephala* (leaf plus fine stem <6 mm in diameter) were harvested from all parts of trees within the university during the late dry season, bulked into three (3) replicates and wilted for two hours. The conserved feeds and *L. leucocephala* were taken for chemical and *in vitro* gas production analyses.

Chemical analyses

Subsamples of each replicate of hay, silage, *L. leucocephala* leaves and forages from the natural grazing land were weighed fresh at the time of collection and then oven dried at 65 °C to constant weight to determine dry matter (DM) content. The dried samples were ground with hammer mill through a 1-mm sieve and analysed for their proximate composition according to AOAC (2000) and fibre contents according to Van Soest *et al*. (1991). Cellulose was determined as the difference between acid detergent fibre (ADF) and acid detergent lignin (ADL), while hemicellulose was determined as the difference between neutral detergent fibre (NDF) and ADF.

In vitro gas production measurement

The *in vitro* gas production was determined following the procedure of Menke and Steingass (1988). Samples (200 mg) of the milled leaf were weighed into 100 ml glass syringes fitted with plungers. Each sample was replicated three times and three blank syringes were included to estimate the net gas production. Macro- and micro-elements, reduction and resazurin dye solutions were mixed together with distilled water and the pH adjusted to 6.9 with buffer solution. Rumen fluid was collected from three West African Dwarf rams (with average weight of 26 kg) according to the method described by Babayemi and Bamikole (2006) before the morning feeding. The animals were fed fresh *P. purpureum* (1 kg/d) and concentrates (200 g/d) (2:1, DM). The rumen fluid was taken to the laboratory, sieved with four layers cheese cloth and added to the anaerobic buffer medium. Thirty ml of the mixture was then added to each syringe. The syringes were placed vertically in a water bath equipped with an electric motor to automatically shake the syringes and temperature regulated at 39°C. Gas production was recorded at 0, 2, 4, 6, 8, 12, 24, 48, 60 and 72 hours of incubation.

The data obtained were fitted to the non-linear regression equation:

P (ml/200 mg DM) = $b \times (1- e^{-c(t-L)})$ (France *et al.*, 2000).

Where P is gas production at time *t*, b is the volume of gas produced from degradable fraction of forage, *c* is the fractional rate of gas production and *L* is the lag time. Initial gas production rate (Absg) was calculated as the product of b and c (McDonald, 1981).

Organic matter digestibility (OMD) was estimated as:

OMD = 14.88 + 0.889 GV + 0.45 CP + 0.651 ash (Menke and Steingass, 1988).

Short-chain fatty acids (SCFA) were estimated as:

SCFA = 0.0239 GV − 0.0601 (Getachew *et al.*, 2000).

Metabolizable energy (ME) was calculated as:

ME = 2.20 + 0.1357 GV + 0.0057 CP + 0.0002859 EE^2 (Menke and Steingass, 1988).

Total gas volume (GV) were expressed as ml/200mg DM, CP and ash as g/kg DM, ME as MJ/kg DM and SCFA as µmol/g DM.

Statistical analysis

Data were subjected to one-way analysis of variance (ANOVA) in a completely randomized design using statistical package (SAS, 1999). Significant means were separated using Duncan's multiple range test (Duncan, 1955).

RESULTS AND DISCUSSION

Chemical analyses

There were significant differences (p<0.05) in the DM content of the feeds with the highest value of 905 g/kg DM in hay and the lowest value of 316 g/kg DM in *L. leucocephala* leaves **(table I)**. The high DM content obtained in hay may be attributed to the effect of sun-drying, while the value obtained in *L. leucocephala* leaves is within the values reported for browse trees in south-western Nigeria (Anele *et al*., 2009). The CP contents ranged from 59 g/kg DM in natural grazing land forages to 171 g/kg DM in *L. leucocephala* leaves. The values of CP obtained in this study for hay and silage were similar to the values reported by Jolaosho *et al*. (2011) for guinea grass–stylo mixture. The CP content of *L. leucocephala* leaves is in the range of CP concentration reported for browses as well as CP of 160-199 g/kg DM reported by Anele *et al*. (2009) for four indigenous multipurpose tree species in Nigeria. The CP obtained for natural pasture fell within the range of 32.2 to 98.2 g/kg DM reported by Kavana *et al*. (2007). Lower CP content recorded for natural pasture may be largely due to moisture stress experienced by the forages during the dry season and coupled with the build-up of lignocellulosic fibre structures in the plants thereby diluting the nutrients (Anele *et al*., 2009). However, except for the natural grazing land forages, the CP contents of the forage resources were above the threshold level of 60 g/kg DM required by the microbes in the rumen to support metabolic functions of their host (Van Soest, 1994). It is interesting to note that the NDF contents of all treatments except natural grazing land forages (705 g/kg DM) were below the 650 g/kg DM suggested as the limit above which the

Table I. Chemical composition (g/kg DM) of hay, *L. leucocephala* leaves, silage and forage samples from natural pasture (Composición química (g/kg DM) de heno, hojas de *L. leucocephala*, ensilaje y muestras de forraje del pasto natural).

Treatment	DM	CP	Fat	Ash	NDF	ADF	ADL	Hem	Cellu
Hay	905.0[a]	92.0[b]	19.7[bc]	79.0[c]	589.0[b]	436.3[a]	175.0[a]	153.0[d]	262.0[ab]
L. leucocephala	316.3[d]	171.4[a]	45.0[a]	169[a]	560.4[b]	381.6[b]	116.0[b]	179.0[c]	266.0[a]
Silage	336.1[c]	108.0[b]	27.7[b]	106[b]	574.4[b]	363.8[b]	128.1[b]	211[b]	236.0[c]
Natural pasture	870.4[a]	59.0[c]	10.9[c]	71.0[c]	705.2[a]	440.6[a]	184.4[a]	265.0[a]	256.2[b]
±SEM	84.72	12.28	3.81	9.88	18.60	10.54	9.02	9.61	3.20

[a, b, c, d]Means in the same column with different letters are significantly different (p<0.05).
DM: dry matter; CP: crude protein; NDF: neutral detergent fibre; ADF: acid detergent fibre; ADL: acid detergent lignin; Hem: hemicellulose; Cellu: cellulose; SEM: standard error of means.

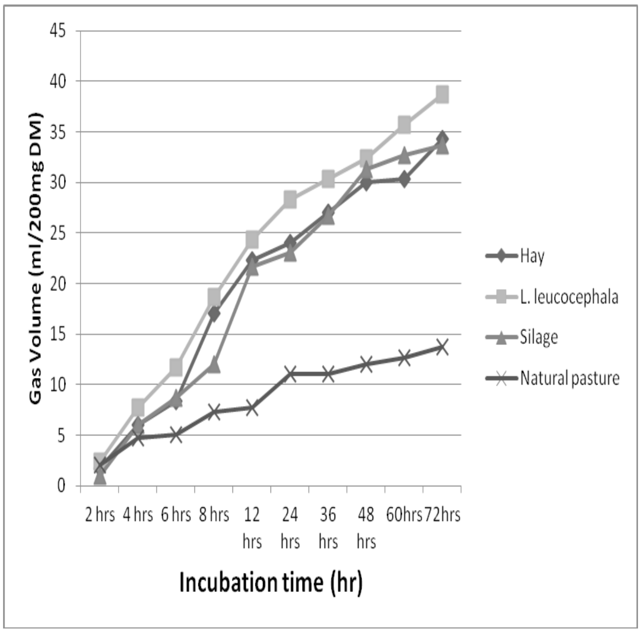

Figure 1. *In vitro* gas production of feed resources from natural pasture (Producción de gas *in vitro* de recursos alimenticios de pastos naturales).

intake of tropical feeds by ruminant animals would be limited (Van Soest, 1994). The NDF and ADF of *L. leucocephala leaves* observed in this study were higher than those reported for *Gliricidia sepium* but consistent with the report of Juma *et al*. (2006).

The fact that the feed resources from the natural grazing land contained above 500 g NDF/kg DM showed that they have fair proportions of soluble carbohydrate which is helpful to maintain a proper rumen function (Oni *et al*., 2008).

In vitro gas production

There were steady increases in the volume of gas production as incubation period progressed from 2 to 72 h **(figure 1)**. The highest volume of 38.7 ml/200 mg DM was recorded for *Leucaena* leaves at the end of the 72 h incubation period. The gas production was higher ($p<0.05$) than what was obtained for hay and silage and also higher than the sample from the natural pastures. Although, gases produced during rumen fermentation are waste products and of no nutritive value to ruminants, however, gas production tests are used routinely in feed research as gas volumes are related to both extent and rate of substrate degradation (Blummel *et al*., 1997). Mebrahtu and Tenaye (1997) reported that the amount of gas released when feeds are incubated *in vitro* is closely related to digestibility of feed for ruminants.

The volume of the gas produced by *L. leucocephala* leaves, hay and silage with increased incubation time, indicated a higher extent of fermentation throughout the incubation periods compared with forages from natural pasture. Highest gas production of *L. leucocephala* leaves, could be due to its higher CP contents that provided nutrients for microorganisms that are responsible for digestion above other feeds resources. This agrees with Reed *et al*. (1990) that leguminous plants contain protein, minerals and vitamins essential for growth of rumen micro-organisms that degrade feedstuff prior to gastric and intestinal digestion by the host animal. It has also been reported that gas production is positively related to microbial protein synthesis.

Fonesca *et al*. (1998) reported that differences in gas production among the feed resources could be due to the extent of lignifications of NDF. The low gas production of natural pasture forages could be due to its higher lignin content, which exerts a strong negative influence on fibre digestion. Lignin has been reported to limits fibre digestion by providing a physical barrier to microbial attack and the concentration of both fibre and lignin increases as plants mature (Chaves *et al*., 2002). Ruminants can digest the cellulose and hemicellulose components of fibre but the lignin inhibits the rate and extent of digestion especially when the proportion of lignin in fibre begins to increase. Some variations among the feed resources could be due to genotypic characteristics including the type of secondary compound activity on digestibility (Salem *et al*., 2006).

In vitro gas production characteristics

Fermentation of the insoluble but degradable fraction (b) values was not significantly ($p>0.05$) different among the hay, silage and the browse plant while forages from natural pasture was lower **(table II)**. This might be as a result of the higher CP content as observed and reported by Akinfemi *et al.* (2009). The fermentation of the insoluble but degradable fraction (b) of the feed resources from the natural pasture for ruminants during the dry season in this study was lower than

Table II. *In vitro* **gas production characteristic of hay,** *L. leucocephala* **leaves, silage and forage samples from natural pasture** (Producción de gas *in vitro* de heno, hojas de *L. leucocephala*, ensilaje y muestras de forraje del pasto natural).

Treatment	b (ml/200 mg DM)	c (ml/h^{-1})	Abs (ml)	Lag time (hr)
Hay	33.9^{a}	0.09	3.19^{a}	1.09
L. leucocephala	35.0^{a}	0.10	3.32^{a}	1.13
Silage	32.4^{a}	0.07	2.26^{ab}	1.13
Natural pasture	12.0^{b}	0.08	0.98^{b}	1.13
SEM	3.41	0.07	0.36	0.24

^{a,b}Means in each column with the different letters are significant ($p<0.05$).
b: Volume of gas produced in time (t); c: Fractional rate of gas production.
Abs: absolute initial gas production during the first hour.
SEM: Standard error of means.

Table III. Metabolizable energy (ME), organic matter digestibility (OMD) and short chain fatty acids (SCFA) of feed resources and forage from natural pasture (Energia metabolizable (ME), digestibilidad de la materia orgánica (OMD) y ácido graso de cadena corta (SCFA) de recursos alimenticios y forraje de pastos naturales).

Treatment	ME (MJ kg^{-1} DM)	OMD (%)	SCFA (µmol)
Hay	8.6b^{c}	45.1^{b}	0.5^{b}
L. leucocephala	16.8^{a}	64.7^{a}	0.8^{a}
Silage	10.7^{b}	55.4^{ab}	0.7^{a}
Natural pasture	5.3^{c}	32.8^{c}	0.2^{c}
SEM	1.48	3.91	0.07

$^{a, b, c}$Means in each column with the different letters are significant (p<0.05).
SEM: Standard error of means.

that reported by Maheri-Sis *et al.* (2007). Khazaal *et al.* (1996) suggested that the intake of a feed is mostly explained by the fractional rate of gas production (c) which affects the rate of passage of the feed through the rumen. Fractional rate of gas production (c) ranged from 0.07-0.10 (h^{-1}) in feed resources from the natural pasture and this was similar to values of 0.00-0.076 (h^{-1}) reported by Babayemi and Bamikole (2006) for Guinea grass/*Tephrosia candida* foliage mixtures. Thus, the higher values obtained for the fractional rate of gas production (c) and absolute initial gas production (Absg) in *L. leucochephala*, hay and silage above forages available in the natural pasture during the dry season, may indicate a better nutrient availability for rumen microorganisms in animals fed with these diets (Getachew *et al.,* 2004).

Post incubation parameters

Metabolisable energy (ME) is a good index for measuring the quality of feeds particularly forages. The ME values **(table III)** of the feed resources obtained in this study was higher than the range (2.99-4.75 MJ/kg DM) reported by Babayemi and Bamikole (2006) for *Tephrosia candida* leaf and its mixtures with Guinea grass but fell within the range reported for several other dry season forages by Babayemi (2007). Metabolisable energy values obtained from the *in vitro* estimation is a major derivative of the volume of gas, which represents the extent and contribution of rumen microbial degradation of feed and digestion of microbial cells. Babayemi and Bamikole (2006) and Mebrahtu and Tenaye (1997) both reported that higher *in vitro* gas production of a feed is an indication of higher digestibility and release of nutrient from feed samples. Metabolisable energy of hay, silage and *L. leucocephala* leaves in this study was in line with NRC (2001) that reported ME content of 8.6 MJ/kg DM for *Pennisetum purpureum* while Arzani *et al*. (2006) reported mean ME content of 7.75 MJ/kg DM for grasses. In a study carried out by Ozelcam *et al.* (2015) on *Lolium multiflorum* (caramba), highest values for *in vivo* metabolizable energy were found in silage and fresh form (7.83 and 7.72 MJ/kg DM respectively), followed by the hay form (6.77 MJ/kg DM). Higher levels of ME in *L. leucocephala* and silage can be explained due to the higher gas volume, contents of crude protein and ether extract. Low ADF and high hemicellulose contents have also been identified as contributors to high ME values. The differences between results obtained from many studies may depend on plant type, vegetation period, soil and climate, because ME value decreases significantly while crude fiber content increases during the vegetation period. The organic matter digestibility (OMD) value of *L. leucocephala* leaves fell within the range obtained by Babayemi (2006) for foliage and fruits of *E. cyclocarpum*. The range of gas volume recorded for these feed resources from the natural pasture indicated that they are capable of producing approximately 50.4 mg/g of microbial mass (Blummel *et al*., 1997). A linear relationship existed between total gas production and ME, OMD and SCFA (Aganga and Mosase, 2001). The high fractional rate of gas production (c) and those of ME and OMD among various factors considered in the present study could translate to higher dry matter intake in ruminants for an improved performance (Babayemi *et al*., 2009). Gas production is a reflection of the generation of short chain fatty acids (SCFA) and microbial mass. The SCFA estimated from the gas production in this study fell within the range reported by Akinfemi *et al.* (2009) and similar to that reported by Sodeinde *et al*. (2009). The SCFA value is an indication that the nutrients in forages will be readily utilized after digestion for maintenance and production. The values obtained in the present study were lower than the range (0.09-1.35 µmol) reported by Babayemi (2007) for some dry season forages.

CONCLUSION

In conclusion, proximate composition, energy content and metabolisable energy through *in vitro* gas production showed that excess forages from the natural pasture that were conserved (hay and silage) as well as *L. leucocephala* leaves could be incorporated as dry season supplements to ruminants that are grazing on poor quality roughages. Livestock farmers should always take the advantage of large quantities of forages in the natural pasture when they are high in quantity and quality during the wet season and utilized them in the dry season when they become coarse, scarce and low in nutrients.

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