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Nutritional evaluation of selected fodder trees: Mulberry (*Molus alba* Lam.), Leucaena (*Leucaena luecocephala* Lam de Wit.) and Moringa (*Moringa oleifera* Lam.) as dry season protein supplements for grazing animals

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Abstract Leaves of Mulberry (*Morus alba* Lam.), Leucaena (*Leucaena leucocephala* Lam de wit.) and Moringa (*Moringa oleifera* Lam.) were evaluated as dry season protein supplements for grazing animals based on chemical composition, in vitro and in sacco nutrient digestibility and a Rabbit feeding trial. All tree fodder forages had similar dry matter (DM) content, but crude protein was higher in Moringa (28.6%) followed by Leucaena (24.5%), Mulberry (24.1%) and Lucerne (18.0%). Ash content was highest in Mulberry followed by Moringa and Lucerne with Leucaena having lowest amounts. Polyphenols ranged from 2.72 to 3.64%, with Leucaena having highest and Mulberry lowest amounts. Dietary fibre were highest in Mulberry and Moringa, but there were no significant differences ($P < 0.05$) between Leucaena and Lucerne. In vitro gas production and DM disappearances were higher in Moringa followed by Mulberry and Lucerne with Leucaena having lowest amounts. Except for Leucaena, DM disappearances were increased when rumen fluid from dairy cattle steers was used. In sacco DM disappearances were 33.7% for Leucaena, 78.2% for Lucerne, 50.2% for Moringa and 50.7% for Mulberry. In vitro and in sacco crude fibre and neutral detergent fibre disappearances were relatively lower, but reflected DM disappearances. The Rabbit feeding trial showed diets based on Moringa, Leucaena and combined fodder forages to have significantly better performance than Mulberry and grass hay alone. The conclusion was that tested tree fodder forages have potential of being used as dry season protein supplements for grazing animals on traditional smallholder farms.

Keywords Moringa · Leucaena · Mulberry fodder trees · In vitro gas production · DM and NDF degradations · Rabbit performance

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Introduction

The main limitation to increased production of ruminants in many parts of sub-Saharan Africa is inadequate supply and availability of quality feeds (Ndlovu and Sibanda 1993; Leng 1990; McSweeney et al. 2001). The situation is particularly dire during the dry season when animals solely depend on natural pastures and crop-residues (Simbaya 2002). Dry season available feedstuffs have low concentration

of digestible nutrients including energy, proteins, vitamins and minerals (Topps 1992). They are however higher in dietary fibre and lignin contents (Devendra 2011), both of which reduce digestibility and subsequent utilization of nutrients. The high fibre content limits rumen microbial fermentation and as such animals grazing natural pastures and crop-residues perform poorly as manifested through reduced body weight gains and milk production levels. In many situations, under fed animals are also more susceptible to parasitic and infectious diseases (Ndlovu and Sibanda 1993). Protein is the main nutrient limiting productivity of animals grazing fibrous feeds during the dry season (Devendra 2011) and many attempts have been made to try and improve protein availability for animals on traditional smallholder farms.

Use of tree fodder forages has been proposed as one of the sustainable means for addressing dry season protein deficiencies for ruminants on traditional smallholder farms (Jetana et al. 2010; Chibinga et al. 2012). This is because tree fodder forages provide a cheap and readily available source of proteins for grazing animals as they contain between 10 and 30% crude protein on dry matter basis (Devendra 2011). Tree fodder forages are also rich in other essential nutrients including soluble carbohydrates, minerals and vitamins (Sánchez 2000; Mtui et al. 2008). Fodder trees have advantage over other feed resources in that they are either produced locally on-farm or grow naturally in surrounding areas and by virtue of being perennial and deep rooted are less susceptible to changing climatic and weather conditions. They have ability to remain green during most part of the dry season when everything else is dry and usually of poor nutritive quality. Being multipurpose they can also be used for many other purposes such as firewood, construction materials and shading off animals against adverse weather conditions (Franzel et al. 2014). Leguminous fodder trees also help to improve soil fertility through atmospheric nitrogen fixation and addition of organic manure when the leaves fall and decay into the soil (Franzel et al. 2014). However, despite these stated advantages, tree fodder forages contain anti-nutritional factors that may have deleterious effects on animal performance including reduced feed intake, body weight loses, reproduction failure and inferior feed conversions (Makkar and Becker 1996; Sanon et al. 2008; Waghorn 2008). This study was undertaken to evaluate use of tree fodder forages; Mulberry (*Molus alba* Lam.), Leucaena (*Leucaena luecocephala* Lam de wit.) and Moringa (*Moringa oleifera* Lam.) as dry season protein supplements for grazing animals using Lucerne (*Medicago sativa*) hay as a control.

Materials and methods

This research was conducted at the University of Zambia (UNZA) in the School of agricultural Sciences. Chemical composition analyses and in vitro digestibility assays were conducted in the Animal Nutrition Laboratory, while in sacco assays and the rabbit feeding trial were done at UNZA Field Station. In vitro gas production, dry matter (DM) and neutral detergent fiber (NDF) degradation assays used rumen fluid collected from two fistulated Merino sheep and two crossbreed dairy cattle steers. The same animals were also used for in sacco DM and NDF degradation assays. Leaves of Mulberry, Moringa and Leucaena trees were collected at random from trees growing on traditional smallholder farms in Kasisi area of Chongwe District. The Rabbits for the feeding trial were purchased from UNZA Department of Biological Sciences in the School of Natural Sciences.

Processing of experimental feed materials

After collection, twigs and leaves of fodder trees were first dried in the shade for two weeks and then subjected to grinding through a 2 mm screen. The dried materials from each tree fodder species were then divided into two portions and sealed in plastic bags until required for chemical composition analysis, in vitro and in sacco degradation assays or the Rabbit feeding trial.

Chemical composition analysis

For chemical composition analysis, all feed materials were again subjected to grinding through a 1 mm screen. All analyses were done in duplicate following the procedures of the Association of Official Analytical Chemists (AOAC 1990). DM in fodder tree leaves was determined by drying samples at 105 °C for 12 h in a temperature controlled oven. Crude protein (CP) was determined by analysing samples for nitrogen

content using Micro Kjeldahl procedures as described in the AOAC (1990) methods. The nitrogen was converted to CP by multiplying nitrogen content by a factor of 6.25. Ether extract (EE) was analysed by extracting samples with petroleum ether for 8 h using a Soxlet apparatus. Ash was determined by incinerating samples at 560 °C for 8 h in a muffle furnace. The ash from each sample was further analysed for calcium and phosphorus using calorimetric and spectrophotometric procedures. Fibre content was determined by analysing samples for neutral detergent fibre (NDF) and acid detergent fibre (ADF) according to the procedures of Goering and Van Soest (1970) with modifications of Mongeau and Brassard (1979). The crude fibre was determined using the Weende procedure (AOAC 1990).

Content of phenolic compounds and tannins were analysed in triplicate according to Makkar (2003) using the Folin–Ciocalteu method. Phenolic compounds were extracted from re-ground (0.5 mm screen) tree fodder forages with 70% aqueous acetone at room temperature. The amount of phenolic compounds in the leaves was expressed as tannic acid equivalents in mg per gram of DM. All analyses were expressed on DM basis.

In vitro gas production and DM and NDF degradation assays

The in vitro gas production was carried out using the method proposed by Menke and Steingass (1988). Approximately 500 mg of each sample was weighed after re-grinding through a 1 mm screen and placed in 120 ml serum bottles in triplicate. Added to each bottle was 42 ml of buffered rumen fluid that also contained macro and trace mineral elements. The rumen fluid used for in vitro incubations was either from two fistulated Merino sheep or two dairy cattle crossbreed steers. In either case, the rumen fluid was collected in thermos vacuum flasks from animals after overnight fasting but prior to morning feeding at 09:00 h. The collected fluid was taken to the laboratory and processed within one hour of collection by filtering through 4 layers of cheese cloth and mixed with a Phosphate buffer solution using a 1:4 ratio. After mixing, readings were taken to record initial pH after which, the bottles were sealed with Teflon rubber stoppers and aluminium crimp cap sealers. The sealed bottles were then incubated in a temperature controlled water bath that was equipped with a shaking mechanism at 39 °C. Cumulative gas production in the bottles were monitored regularly using 50 ml plastic needle syringes for up to 24 h. After incubations, bottles were placed on ice to terminate microbial fermentations. The bottles were then opened to take pH readings to monitor changes over the 24 h incubation period. Samples were then transferred into weighed ADF/NDF Ankhom filter bags. The contents of the bags were then washed with water and rinsed with acetone before drying at 50 °C for 48 h. After drying, the samples were weighed after equilibrating to room temperature in a desiccator to determine DM disappearances. The DM was latter subjected ADF and NDF analysis to determine their disappearances.

In Sacco DM and NDF degradation assays

Two rumen fistulated Merino sheep were used for determining in sacco degradation of DM, NDF and ADF in leaves tree fodder forages. The sheep were maintained on a standard dairy diet comprising of concentrates and grass hay. For incubations, approximately 2.0 g of each sample was sealed in nylon bags in triplicate. Two glass marbles were placed in each bag to help samples sink into the rumen fluid during incubation. Incubations were allowed for 24 h, after which they were removed and put on ice to terminate fermentation and latter washed under running tap water before being rinsed with acetone and dried at 50 °C for 48 h to determine DM remaining in the bags. Residues from each bag were latter analysed for NDF and ADF to determine disappearances from initial samples.

Rabbit feeding trial

The feeding trial used 20 Rabbits of non-descriptive breed that were reared individually in cages in a temperature controlled room (2 °C). The first three treatments were based on grass hay (Napier grass) that was combined with leaves of experimental fodder trees using a 50 to 50% combination ratio. The fourth treatment consisted of an equal mixture of all three tree fodder forages that were mixed with an equal amount of grass hay, while the fifth treatment was made up of only grass hay. Each treatment was given to 4 Rabbits that were used as replicates. Each Rabbit was given weighed amounts of dried experimental

feed once every day and feed intake was measured by weighing amounts remaining from what was given the previous day. Throughout the trial, rabbits had free access to feed and water. To monitor body weight changes, the rabbits were weighed once every week and feed conversion ratio was calculated by dividing feed intake with weights gained over the same period.

Experimental design and statistical analysis

The study was conducted as a completely randomised design and all collected data were subjected to analysis of variance (ANOVA) using Minitab 16 statistical software package to identify presence of significant differences among treatment means. The significantly different means were separated from each other using Tukey's test of comparison at a confidence level of 95%.

Results and discussion

In Table 1, DM content ranged from 88.40 to 92.56% with Leucaena having the highest amount and Mulberry the lowest. However, despite numerical variations, all tree fodder forages contained statistically similar amounts of DM ($P \geq 0.05$). The reported DM figures were comparable with findings of Maasdorp et al. (1999), who found 91.7% to be the average DM content for tree fodder forages in Zimbabwe. The current figures were however, lower than the 94.3 to 96.2% reported as DM contents for native fodder trees in Tanzania (Selemani et al. 2013). Generally, DM contents in feedstuffs depend on the type, level of maturity and drying conditions to which feed materials are exposed. The CP content was highest in Moringa followed by Leucaena and Mulberry leaves that had similar amounts with Lucerne having lowest amounts. This may be a confirmation to earlier suggestions that tree fodder forages have relatively higher CP contents when compared with herbaceous legumes like Lucerne (Mahipala et al. 2009). Crude protein content tends to vary in forages of fodder trees based on the source, age and type of tree species (Maasdorp et al. 1999; Jetana et al. 2010; Piñeiro-Vázquez et al. 2017). The EE content was also significantly different among tree fodder forages with highest amounts being recorded in Moringa, followed by Mulberry and Lucerne with Leucaena having the lowest. Generally, EE content in tree fodder forages is usually low and has been reported to fall between 2.34 and 5.92% (Girma et al. 2015). The ash content was highest in Mulberry followed by Moringa with Lucerne and Leucaena having statistically ($P < 0.05$) similar amounts. In a Tanzanian study, ash contents in leaves of a variety of fodder trees were found to vary between 29 and 179 g/kg DM, an indication of variability in ash contents among tree fodder forages (Mahipala et al. 2009). In a more recent study, Selemani et al. (2013) reported ash contents in browse fodder trees to vary between 7.16 and 13.58% and considerable variations were noted between the rainy and dry season. The current high ash content in mulberry leaves are consistent with findings of Kandylis et al. (2009) who recorded figures as high as 163 g/kg DM. The calcium levels were highest in Mulberry followed by Moringa with Leacaena and Lucerne having lower, but similar amounts. The phosphorus content ranged

Table 1 Nutrient composition of tree fodder forages in comparison with that of Lucerne hay (%)

Nutrient	Moringa	Mulberry	Leucaena	Lucerne	SEM
Dry matter	90.08 ± 0.29	88.40 ± 3.08	92.56 ± 2.95	91.31 ± 0.32	2.14
Crude Protein	28.63^{a} ± 0.02	24.05^{b} ± 0.43	24.5^{b} ± 0.36	18.02^{c} ± 1.55	0.83
Ether Extract	6.80^{a} ± 0.29	6.02^{b} ± 0.05	2.76^{d} ± 0.04	3.63^{c} ± 0.15	0.17
Ash	9.97^{b} ± 0.23	14.87^{a} ± 0.19	7.22^{c} ± 0.09	7.48^{c} ± 0.11	0.20
Calcium	2.07^{b} ± 0.10	2.90^{a} ≤ 0.15	1.26^{c} ± 0.12	1.36^{c} ± 0.08	1.12
Phosphorus	0.24^{a} ± 0.02	0.17^{b} ± 0.04	0.20^{ab} ± 0.15	$0.10a^{b}$ ± 0.02	0.03

SEM standard error of the mean

Means with different superscript letters within a column were significantly different from each other at $P \leq 0.05$. Figures represent mean ± standard deviation

between 0.10 and 0.24% with highest levels in Moringa and Luecaena followed by Mulberry and Lucerne that had slightly lower but similar to what was in Leucaena. As pointed out above, variations in ash and mineral contents among tree fodder forages tend to reflect differences in soil types and growing conditions rather than fodder tree species (Gebeyew et al. (2015).

The amount of anti-nutritional factors in tree fodder forages were presented as total polyphenols and dietary fibre (Table 2). Total phenolic compounds were significantly higher in Leucaena with the rest of the fodder trees having similar amounts with what was in Lucerne. The same pattern was recorded in a similar study that looked at Leucaena, Mulberry and Moringa, where the amounts for Leucaena were much higher than the current figures (Mahipala et al. 2009). A study by Piñeiro-Vázquez et al. (2017) reported Leucaena leaves to have between 7.7 and 20.0 g/kg DM as total polyphenols and condensed tannins, respectively. The 3.05% total polyphenols for Moringa in the current study are comparable with 34 g/kg DM reported by Makkar and Becker (1996) in un-extracted Moringa leaves. In another study, the total phenols, total tannins and condensed tannins were; respectively found to average 139, 113 and 43 mg/g of browse fodder trees in Tanzania (Rubanza et al. 2003), while a study from Western Australia (Mahipala et al. 2009) reported total phenols in fodder trees to range from 3.4 to 44.3 g/kg DM (Tables 3. 4, 5), an indication of variability of these compounds in fodder trees. Earlier findings in our laboratory found total polyphenols to be highest in Leucaena (12.71%) compared to Moringa (4.45%) and Mulberry (3.74%). The content of condensed tannins were much lower averaging 1.41% for Leucaena, 0.504% for Moringa and 0.062 for mulberry leaves. The content of hydrolysable tannins in the same leaves were 3.59 for Luecaena, 2.10 for Moringa and 0.84 for Mulberry. These findings seem to confirm earlier reports that concluded Leucaena to have more polyphenols than other tree fodder forages (Balgees et al. 2013). It must also be appreciated that the amount of polyphenols in tree fodder forages tend to be influenced by level of leaf maturity and the stress or hazards in growing conditions to which the plants are exposed. Younger leaves are more concentrated in tannins and other polyphenols compared with older or mature leaves.

The NDF content ranged from 45.78 to 65.28% with Moringa having significantly higher amounts followed by Mulberry leaves. Lowest NDF amounts were recorded in Leucaena and Lucerne that had statistically similar amounts ($P < 0.05$). The NDF amounts in Moringa and Mulberry leaves were comparable with the findings of Selemani et al. (2013), who found NDF contents in Tanzanian native fodder trees to vary between 63.3 and 79.5%. Other studies have reported much lower NDF figures that seem to agree with the current findings on Leucaena and Lucerne (Rubanza et al. 2003; Girma et al. 2015). ADF contents reflected NDF figures with highest amounts being recorded in Moringa followed by Mulberry and Luecaena with Lucerne having the least amounts. All tree fodder forages had relatively lower CF content and there were no statistical differences among the tested tree fodder forages including Lucerne.

Table 2 Content (%) of polyphenols and various dietary fibre components in tree fodder forages expressed as percentage of dry matter content

Type of fodder	Total phenols	NDF	CF	ADF
Moringa	$3.05^{b} \pm 0.31$	$65.28^{a} \pm 1.89$	12.42 ± 3.37	$45.24^{a} \pm 5.99$
Mulberry	$2.72^{b} \pm 0.27$	$61.13^{b}1.91$	15.23 ± 0.76	$33.33^{b} \pm 1.24$
Leucaena	$3.64^{a} \pm 0.08$	$45.78^{c} \pm 1.37$	12.64 ± 0.77	$32.64^{bc} \pm 1.61$
Lucerne	$2.75^{b} \pm 0.08$	$46.51^{c} \pm 0.04$	14.69 ± 0.55	$24.30^{c} \pm 2.70$
SEM	0.22	1.32	1.79	3.44

SEM standard error of the mean

Means with different superscript letters within a column were significantly different from each other at $P \leq 0.05$. Figures represent mean ± standard deviation

Table 3 Changes in gas production (ml) and pH readings after incubating tree fodder forages in rumen fluid of Merino sheep or crossbred dairy cattle steers over a 24 h period

Type of fodder	Sheep Rumen Fluid		Cattle Rumen Fluid	
	Gas Production	pH Reading	Gas Production	pH Reading
Blank	4.4 ± 0.2	6.8	2.1 ± 0.3	7.9
Leucaena	17.2 ± 2.1	6.7	31.6 ± 8.4	7.6
Moringa	40.3 ± 1.8	6.4	37.4 ± 2.2	7.0
Mulberry	34.6 ± 1.3	6.5	37.2 ± 11.2	7.2
Lucerne	31.3 ± 0.9	6.6	22.3 ± 6.2	7.2

Figures in the Table represent mean ± standard deviation

Table 4 In vitro dry matter disappearances (%) of tree fodder forages when incubated for 24 h in buffered rumen fluid of Merino sheep or crossbred dairy cattle steers

Type of fodder	Merino sheep fluid	Dairy cattle fluid
Leucaena	7.46^{c} ± 0.3	5.09^{b} ± 0.46
Moringa	14.65^{a} ± 0.29	24.26^{a} ± 4.81
Mulberry	14.91^{a} ± 0.3	28.35^{a} ± 2.87
Lucerne	11.53^{b} ± 0.47	21.94^{a} ± 0.41
SEM	0.32	3.35

SEM standard error of the mean

Means with different superscript letters within a column were significantly different from each other at $P \leq 0.05$. Figures represent mean ± standard deviation

In vitro incubation of tree fodder forages in the rumen fluid of Merino sheep showed Moringa to have produced highest amounts of gas followed by Mulberry and Lucerne. The pH readings at the end of incubation, showed Moringa to have relatively lower readings followed by Mulberry and Lucerne. The same pattern was noted when rumen fluid of dairy steers was used for in vitro incubations. Due to increased sample variations, there were no statistical differences among the various tree fodder forages in cumulated gas production. Increased gas production levels were an indication of increased fermentation, which was supported by a reduction in pH readings reflecting an increase in the production of volatile fatty acids. The reduction in the production of gases in Leucaena may be associated with increased concentration of polyphenols that are known to affect microbial fermentation (Makkar and Becker 1996). Polyphenols and tannins are known to limit rumen microbial fermentation by binding to proteins and reducing enzymes and microbial activities (Waghorn 2008). In vitro DM degradations were highest in Moringa followed by Mulberry when samples were incubated in rumen fluid of sheep. When dairy cattle steers rumen fluid was used, degradation of Leuceana leaves was somehow improved. Though slightly higher, the pH readings after incubation of samples in rumen fluid of dairy cattle steers also reflected

Table 5 In sacco degradation of dry matter, neutral detergent fibre and acid detergent fibre after 24 h of incubating tree fodder forages in the rumen of Merino Sheep or dairy cattle steers

Type of fodder	Dry matter	Neutral detergent fibre	Acid detergent fibre
Leucaena	3.36^{b} ± 5.74	24.20 ± 3.46	11.67^{ab} ± 3.53
Moringa	50.19^{a} ± 3.1	20.18 ± 1.65	10.67^{b} ± 0.57
Mulberry	50.72^{a} ± 4.14	18.34 ± 2.13	16.52^{a} ± 2.38
Lucerne	7.82^{b} ± 1.57	18.18 ± 4.99	12.78^{ab} ± 4.00
SEM	3.94	3.32	2.94

SEM standard error of the mean

Means with different superscript letters within a column were significantly different from each other at $P \leq 0.05$

Table 6 Total feed intake (g), body weight gains (g) and feed conversion ratios of growing Rabbits fed 50:50 grass to fodder tree mixtures over a period of 4 weeks

Type of fodder	Feed intake (g)	Body weight gain	Feed conversion ratio
Moringa	469.63^{c}	133.25^{a}	3.50^{c}
Mulberry	513.35^{c}	112.65^{b}	4.60^{b}
Leucaena	547.23^{b}	127.23^{ab}	4.33^{bc}
Forage mixture	525.85^{b}	140.60^{a}	3.75^{bc}
Grass alone	610.92^{a}	56.90^{c}	10.85^{a}
SEM	22.80	22.80	0.47

SEM standard error of the mean

Means with different superscript letters within a column were significantly different from each other at $P \leq 0.05$.

increased fermentation of Moringa, Mulberry and Lucerne. Similar findings were noted by Singh and Kundu (2010) in sheep fed grass hay supplemented fodder tree leaves. The same pattern was also reflected for DM disappearances from in vitro incubations. Mulberry leaves showed slightly better DM disappearances followed by that of Moringa and Lucerne. The disappearance of DM was almost doubled when rumen fluid from dairy cattle steers was used. However, due to increased variability among samples, there were no statistical differences among treatments. Similarly higher gas production and increased in vitro DM disappearances were noted by Nouala et al. (2006) when *Moriga oleifera* leaves were incubated with ground nut hay when compared with that of conventional concentrates. Findings on in sacco DM and fibre disappearances were as indicated in Table 6 and both showed Leucaena and Lucerne to promote inferior DM disappearances. There were however, no significant differences ($P > 0.05$) in the disappearance of NDF among tree fodder forages. On the other hand, ADF disappearances were significantly higher in Mulberry, although it did not differ with that of Leucaena and Lucerne. The results on DMD were comparable with findings of Selemani et al. (2013) who reported a variations of between 30.51 and 57.8% as in vitro DMD among key tree fodder forage species in Tanzania.

Results of the Rabbit feeding trial were as presented in Table 6 and show that the Rabbits fed the grass only diet to have had a significantly higher feed intake that was followed by that of those fed diets based on Leucaena and a combination of all three tree fodder leaves. The least amount of feed intake was in Rabbits fed grass mixed with Moringa and mulberry leaves. The results on feed intake were in agreement with findings of Weldegebriel et al. (2014) who also reported increased feed intake in sheep fed protein un-supplemented diets when compared with that of sheep fed diets supplemented with tree fodder forages. The increase in feed intake among rabbits fed grass hay alone may be explained by the fact that these animals were trying to meet limited energy and protein requirements from the basal diet. This may also explain the reduced feed intake among rabbits fed Moringa based diet as they could easily meet their requirements from the high dietary nutrient contents. In terms of body weight gains, the Rabbits fed a combination of three tree fodder forages had better performance, even though their performance was statistically similar ($P > 0.05$) to that of rabbits fed Moringa and Leucaena fodder tree based diets. As expected, Rabbits fed grass hay alone without any protein source had inferior body weight gains. The results on feed conversion reflected that of body weight gains with Rabbits fed diets based on Moringa, Leucaena and the combined fodder trees giving better performance followed by that of mulberry leaves based diet, with grass hay alone giving least performance. This may be an indication that tree fodder forages could be used to improve performance of grazing animals during the dry season. Apparently, increased concentration of polyphenols in Leucaena did not adversely affect performance of Rabbits in the current study.

Conclusion

Results from this study demonstrate potential of tested tree fodder forages as protein supplements for animals

grazing fibrous feeds in the dry season. Results on chemical composition, showed Moringa leaves to have a better nutritional profile that was followed by that of Mulberry and Lucerne. Leucaena had a considerably higher content of polyphenols that may have limited in vitro gas production and degradation of DM and NDF components. The high nutritional profile of Moringa, Mulberry and Lucerne were demonstrated by increased degradation of nutrients in both in vitro and in sacco assays that were confirmed by the Rabbit feeding trial in terms of body weight gains and feed conversion ratios.

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