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Research Article

The Potential of *Acacia polyacantha* Leaf Meal and *Adansonia digitata* Seedcake for Small Ruminant Feeding in Arid and Semi-Arid Parts of Malawi

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Abstract

The potential of *Acacia polyacantha* and *Adansonia digitata* for small ruminant feeding was evaluated through nutrient analysis, *in vitro* gas production and determination of organic matter digestibility, metabolizable energy, short chain fatty acids and methane production. *Adansonia digitata* seedcake and *Acacia polyacantha* leaves were analyzed along with *Glycine max* meal and *Chloris gayana* hay, which were common feed supplements to grazing goats at Bunda farm. Results from the study revealed that *Acacia polyacantha* leaf meal (212.3 g/kg DM) had higher CP than *Chloris gayana* hay (74.0 g/kg DM) but less than that of *Adansonia digitata* seedcake (310.5g/kg DM) which was lower than that of *Glycine max* (397.5 g/kg DM) ($P < 0.05$). Gas production (24 hours), OMD, ME and SCFA was similarly higher in *Adansonia digitata* and *Glycine max*. Least methane production was observed in *Acacia polyacantha*. It was concluded from the study that *Adansonia digitata* can be utilized for small ruminant production in arid and semi-arid parts of Malawi and that incorporation of right amounts of *Acacia polyacantha* in small ruminant diets could reduce enteric methane production and improve small ruminant productivity.

Keywords: *Dry Season; In Vitro Gas Production; Methane; Non-Conventional Protein Sources*

Abbreviations

ADF: Acid Detergent Fibre; CP: Crude Protein; DM: Dry Matter; EE: Ether Extract; ME: Metabolizable Energy; NDF: Neutral Detergent Fibre; OMD: Organic Matter Digestibility; SCFA: Short-Chain Fatty Acids; VFA: Volatile Fatty Aids

Introduction

A major challenge to agricultural scientists and policy makers globally is providing adequate good-quality feed to livestock in order to improve and maintain their productivity while mitigating climate change. In tropical countries the traditional ruminant livestock feeding system mainly depends on the use of native grasses, legumes, and other foliage [14]. Under such systems livestock production is constrained by scarcity and fluctuating quantity and quality of the year-round feed supply during the dry season [13]. As a result, animals consume higher quantity of less palatable species which consequently results in loss of body weight [9].

Promotion of concentrate feeding to improve low quality dry season feeds is limited by high competition with humans as well as soaring cost. It was stated [6] that high competition for consumption of conventional protein sources between human beings and the livestock industry in the last two decades has resulted in an inadequate supply of dietary proteins. On the other hand, high cost of conventional protein concentrates prevents their use in smallholder ruminant production systems in Sub-Saharan Africa [1]. Therefore, there is a need to exploit non-conventional protein sources. Research on low-cost and locally available indigenous protein sources is very important, especially those which do not attract competition with human beings and the ever-expanding intensive livestock production. The use of local indigenous multipurpose tree products and by-products, such as seed cakes and leaf meals is one such possible alternatives. Utilization of non-conventional feedstuffs especially when it encourages a shift to other ingredients that are not edible to man but readily available will reduce the cost of feed and maximize the returns from small ruminant production.

Reports have indicated that one of the potential low-cost and locally available protein sources in small ruminant diets is *Adansonia digitata* (baobab) seed cake [14]. Another potential non-conventional source of protein is *Acacia polyacantha* (white thorn tree) leaf meal. Other acacia species including *Acacia brevispica, Acacia nubica, Acacia tortilis, Acacia seyal, Acacia nilotica* and *Acacia mellifera* have been shown to contain appreciable crude protein (134 - 213 gkg^{-1}DM) and minerals [5].

However, there is limited information about the feeding value of *Adansonia digitata* seedcake and *Acacia polyacantha* leaf meal as feed for small ruminants in Malawi. As such, the use of nutrient analysis in combination with *in vitro* gas production technique can be a useful tool for preliminary evaluation of nutritive value of these feed sources. Therefore, this study evaluated the nutritive value of *Acacia polyacantha* and *Adansonia digitata* by nutrient analysis, and gas production technique *in vitro*, organic matter digestibility, metabolizable energy, short chain fatty acids and methane production.

Materials and Methods

Study location and feed samples

The study was conducted at Bunda farm, Lilongwe University of Agriculture and Natural Resources (LUANAR), Malawi. The farm is located at an elevation of 1158m above the sea level at latitudes 14.18^{o}S and longitudes 33.76^{o}E. The area experiences a sub-tropical climate with three marked seasons: cool dry (May-August), hot dry (September-November) and wet season (December-April). The average daily maximum temperature for the area is 27^{o}C and receives annual rainfall of 800 - 1000 mm. *Adansonia digitata* seedcake and *Acacia polyacantha* leaves were analyzed along with *Glycine max* (Soya bean) and C*hloris gayana* (Rhodes grass) hay which were commonly used supplemental feeds to grazing goats at Bunda farm, small ruminant section. *Acacia polyacantha* leaves and *Chloris gayana* were harvested at Bunda farm. *Acacia polyacantha* leaves were harvested by cutting branches when the plants had reached full maturity between the months of May and April. After sun-drying the leaves on a concrete floor for 2 days, they were then collected from the concrete floor after whipping the branches with a stick. The leaves were then sieved to remove any thorns and twigs. *Chloris gayana* was cut using a sickle, dried in the shed for 4 days in preparation for laboratory analysis. *Adansonia digitata* seedcake which is a by-product from baobab oil processing was bought from a local company in Lilongwe City that processes baobab oil and baobab fruit pulp juices. *Glycine max* was purchased from agricultural and veterinary input shops around Bunda farm. Feed samples were transported to the Animal Nutrition Research laboratory at Bunda campus, LUANAR.

Nutrient composition analysis

The samples were dried in an oven to a constant weight and then ground using a Wiley Laboratory mill to pass through a 1 millimeter sieve. Nutrient composition of feed samples was carried out following [2] standard procedures for determination of dry matter (DM), ash, ether extract (EE), and total nitrogen (N). Crude protein (CP) was obtained by multiplying N in feeds by the factor (6.25). Methods of van Soest., *et al*. [26] were used to analyze fibre components of the feed samples, neutral detergent fibre (NDF) and acid detergent fibre (ADF), using the ANKOM^{200} Fiber Analyzer (ANKOM Technology Corp., Fairport, NY).

In vitro gas production

Based on the assumption that the volume of gas produced reflects the end result of the fermentation of the substrate to volatile fatty acids (VFA), the *in vitro* gas production technique is a useful tool to determine the nutritional value of forages consumed by ruminants. Feed samples were incubated *in vitro* with rumen fluid in calibrated glass syringes following the procedure of [19]. Rumen liquor was obtained from three fistulated local goats before morning feeding. About 200 mg of a sample was weighed into 100 ml calibrated glass syringes in triplicates. About 30 ml of rumen-buffer mixture was added into each syringe and then all the syringes were incubated in a water bath maintained at 39°C. The syringes were gently shaken every hour during the first 8 hours of incubation. Readings were recorded after 4, 8, 12, 24, 36 and 48 hours.

Feed organic matter digestibility (OMD) (%) and metabolizable energy (ME) (MJkg^{-1} DM) were estimated from the following [18,19] equations based on 24h gas production (Gv, ml) and crude protein content (CP, %):

OMD (%) = 14.88+0.889*Gv +0.45*CP

ME (MJkg^{-1} DM) = 2.20 +0.136*Gv + 0.057*CP.

In addition, short chain fatty acids (SCFA) were calculated as reported by [3]: SCFA = 0.0239*Gv – 0.0601.

Estimation of methane gas

As described by [10], 4 ml of sodium hydroxide (NaOH) (10M) were introduced into the gas syringes, 24 hours post incubation, to estimate methane production. In this procedure, NaOH reacts with carbon dioxide in the calibrated glass syringes such that the remaining gas is mostly methane gas. The merit of this method is that it is less costly and reliable in ranking ruminant feed in terms of enteric methane production.

Statistical analysis

Analysis of variance (ANOVA) was performed on nutrient composition, *in vitro* gas production, methane gas production, metabolizable energy and organic matter degradability of major feed ingredients using General Linear Model procedures in R version 3.5.1. The statistical significance of the differences between means was tested using Tukey Honestly Significance Difference at 95% confidence level. The statistical model that was used was as follows; $Y_{ij} = \mu + \beta_i + \mathcal{E}_{ij},$ where Y_{ij} is the response variable, μ is the overall mean, β_i is the independent variable (feed sample), and $\mathcal{E}_{ij}$ is the random error component.

Results and Discussion

Nutrient composition

Nutrient composition results are presented in table 1. There were significant differences (P < 0.05) in the nutrient composition of selected feeds except for DM which did not vary. CP ranged from 74.0 g/kg DM to 397.5 g/kg DM with *Glycine max* having the highest content. The CP content of *Glycine max* was significantly higher than that of *Adansonia digitata* (P < 0.05). *Acacia polyacantha* leaf meal had higher CP than *Chloris gayana* hay but less than that of *Adansonia digitata* seedcake (P < 0.05). The CP content of *Acacia polyacantha* determined in this study was lower than the 281.0 g/kg reported by [20] in semi-arid central Tanzania. However, CP content of *Acacia polyacantha* obtained in this study was comparable to that obtained by [24] in north-western Tanzania. Furthermore, CP content of *Acacia polyacantha* found in this study was higher than that of other Acacia species viz. *Acacia shaffneri, Acacia abyssinica and Acacia ampliceps*

[4,5]. The CP content of *Adansonia digitata* seedcake used in this study was higher than the value of 204 g/kg DM reported in baobab seed cake reported by [22] and the value of 201.3 g/kg DM reported by [16]. Apart from *Chloris gayana* hay, the CP contents of all other feeds were above 110 - 130 g/kg DM CP which is the adequate range for growth and maintenance [20]. Relatively high contents of CP in *Adansonia digitata* seedcake and *Acacia Polyacantha* leaves support their potential as feedstuffs for goats in arid and semi-arid regions parts of Malawi. Variations in CP content could be explained by specie differences and this can be ascribed to inherent characteristics of each species' ability to extract and accumulate nutrients from the soil [8].

Selected feeds	DM	CP	NDF	ADF	Fat	Ash
Glycine max meal	911.3	397.5^{d}	379.9^{a}	292.3^{a}	224.6^{c}	53.0^{a}
Adansonia digitata seedcake	904.4	310.5^{c}	465.4^{b}	298.0^{a}	130.8^{b}	53.8^{a}
Acacia polyacantha	898.0	212.3^{b}	692.1^{c}	342.2^{a}	38.3^{a}	88.5^{b}
Chloris gayana hay	894.2	74.0^{a}	758.2^{c}	540.6^{b}	22.1^{a}	86.3^{b}
SEM	0.523	12.51	19.10	22.16	5.08	3.16
P-value	0.103	<.000	<.000	0.001	<.000	<.000

Table 1: *Nutrient composition of selected goat feeds (g/kg DM).*

According to [27], the major determinants of overall forage quality are NDF and ADF. The NDF and ADF content of feeds in this study ranged from 379.9 g/kg DM to 758.2 g/kg DM and 292.3 to 540.7 g/kg DM, respectively. The NDF of *Chloris gayana* hay was significantly higher ($P < 0.05$) than that of the other ingredients except that of *Acacia polyacantha* which was similar ($P > 0.05$). In terms of ADF, *Chloris gayana* hay had significantly higher ($P < 0.05$) ADF than all other ingredients. Moderate content of NDF in baobab seedcake is indicative of comparatively high digestibility. On the contrary, high NDF content in *Acacia polyacantha* observed in this study would be suggestive of low digestibility which could have an adverse impact on animal performance. As highlighted by [12], the safe upper NDF limit for small ruminants is 60%. At least 25% of fibre, measured as neutral detergent fibre, is recommended by NRC [21].

Fat content in the feed ingredients ranged from 22.1 g/kg DM to 224.6 g/kg DM with *Glycine max* having the highest fat content and seconded by baobab seedcake. Rhodes grass hay had the least fat content. Ingredient ash content ranged from 37.9 g/kg DM to 88.5 g/kg DM. The highest ash content was observed in *Acacia polyacantha* even though it was not significantly different from that of *Chloris gayana* hay. The differences in chemical composition could be due to several factors that can affect chemical composition of feed, such as stage of growth maturity, species or variety, soil types and growth environment [7].

Gas production profiles of feeds

In vitro gas production results of selected feeds after 4, 8, 12, 24, 36 and 48 hours of incubation are presented in table 2. Gas production (GP) provides a useful basis from which ME, OMD and SCFA could be estimated even though it is a nutritionally wasteful product [17]. GP is usually associated with volatile fatty acid production following fermentation of substrate [15].

Selected feeds	4hrs	8hrs	12hrs	24hrs	36hrs	48hrs
Glycine max	10.65^{a}	20.88^{b}	33.23^{c}	53.52^{c}	63.97^{bc}	67.85^{c}
Adansonia digitata	16.43^{b}	27.03^{c}	35.48^{c}	51.83^{c}	64.47^{c}	68.52^{c}
Acacia polyacantha	7.21^{a}	11.64^{a}	16.92^{a}	24.17^{a}	33.94^{a}	41.6^{a}
Chloris gayana	10.74^{a}	17.43^{b}	24.25^{b}	34.81^{b}	52.28^{b}	57.07^{b}
SEM	1.18	1.51	1.54	2.92	3.75	2.70
P-value	<.001	<.001	<.000	<.000	0.000	<.000

Table 2: *Cumulative gas production of selected goat feeds after 4, 8, 12, 24, 36 and 48 (mL/200 mg substrate).*

There was considerable variation in terms of gas production among selected feeds throughout the incubation periods. Cumulative gas production was significantly different (P < 0.05) at 4, 8, 12, 24, 36 and 48 hours. Higher gas production was recorded in *Adansonia digitata* seedcake and *Glycine max* which had similar gas volumes. Intermediate gas production was observed in *Chloris gayana* hay, whereas *Acacia polyacantha* had the least gas recordings. Relatively low gas production in *Acacia polyacantha* and *Chloris gayana* hay might be due to higher NDF content which as stated by [3] could result into reduction of microbial activity during the incubation process. The presence of tannins has been reported in *Acacia polyacantha* [25]. Therefore, least gas productions in *Acacia polyacantha* in this study could further be attributed to the presence of phenolic compounds which adversely affect microbial activity [23].

Table 3 indicates the correlation of nutrient composition and gas production at 24h. A positive correlation (r = 0.72) was observed between CP content of feed ingredients and cumulative gas production at 24h incubation. The presence of high nitrogen in the rumen promotes microbial multiplication thereby improving fermentation of substrates in the rumen and consequently leading to increased gas production. On the other hand, low nitrogen levels limit substrate fermentation hence low gas production since gas production is a function of fermentation. Negative correlations were observed between cumulative gas production at 24h incubation and NDF and ADF with correlation coefficients -0.88 and -0.47, respectively. Potential gas production decreased with increased NDF and ADF. The findings are consistent with reports by [5,11].

	GP24h	CP	NDF	ADF
GP24h	1	0.72	-0.88	-0.47
CP		1	-0.96	-0.92
NDF			1	0.81
ADF				1

Table 3: *Correlation (r) between nutrient composition and cumulative gas production at 24 hours.*

Estimated organic matter digestibility (OMD), metabolizable energy (ME), methane (CH4) production, and short chain fatty acid (SCFA) for feed ingredients

Estimated organic matter digestibility (OMD) (%), metabolizable energy (ME) (MJ/kg DM), short chain fatty acid (mol) and enteric methane (ml/200 mg substrate) are shown in table 4. The estimated OMD ranged from 45.93 to 77.01% and was significantly (P < 0.05) higher in *Glycine max* and *Adansonia digitata* seedcake than in *Acacia Polyacantha* and *Chloris gayana* hay. The ascending order of feed ingredients based on estimated OMD was *Acacia polyacantha* < *Chloris gayana* < *Adansonia digitata* seedcake < *Glycine max*. Higher OMD implies that the rumen microbes and the animal have high nutrient uptake [3].

Selected feeds	OMD	ME	Methane	SCFA
Glycine max	77.01^{b}	11.41^{b}	8.75^{b}	1.22^{c}
Adansonia digitata seedcake	74.93^{b}	11.02^{b}	7.53^{b}	1.18^{c}
Acacia polyacantha	45.93^{a}	6.70^{a}	4.42^{a}	0.52^{a}
Chloris gayana	49.16^{a}	7.36^{a}	8.92^{b}	0.77^{b}
SEM	2.04	0.30	0.67	0.07
P-value	<.000	<.000	0.000	<.000

Table 4: *Estimated OMD, ME, Methane and SCFA of selected goat feeds.*

Methane varied significantly among the feeds. It ranged from 4.42 to 8.92 ml/200 mg substrate. In the study, methane produced from *Acacia polyacantha* was significantly lower than that of *Glycine max*, *Adansonia digitata* seedcake and *Chloris gayana* which were on the other hand not different. The least methane production in *Acacia polyacantha* could be due to presence of high phenolic compounds (tannins) which suppresses microbial activity [23].

Glycine max and *Adansonia digitata* seedcake had the highest ME. A strong correlation was reported by [19] between ME values measured *in vivo* and predicted from 24h *in vitro* gas production and nutrient composition of feed. Therefore, the higher the ME calculated, the greater the potential to be used as ruminant feed.

The SCFAs predicted from gas production were 0.52 µM, 0.77 µM, 1.18 µM and 1.22 µM for *Acacia polyacantha*, *Chloris gayana*, *Adansonia digitata* seedcake and *Glycine max* respectively. Estimated SCFAs were significantly different with higher values obtained from *Glycine max* and *Adansonia digitata* seedcake which were similar. High predicted SCFA values signify high energy availability while low values of SCFA indicate low energy available. *Acacia polyacantha* had the least predicted SCFA.

Conclusion

- The nutritive composition, *in vitro* gas production, OMD, ME and SCFA in *Adansonia digitata* seedcake showed a potentially high CP and energy available, suggesting its possibility of being utilized for small ruminant production in arid and semi-arid parts of Malawi.
- Low methane production in *Acacia polyacantha* signifies a great potential to increase feed utilization efficiency by reducing dietary energy losses but also reduce enteric methane emissions if used as a supplement to low quality forages in the right amounts.

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