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Ameliorative effects of *Ficus* and *Harrisonia* diets on Small East African goat meat yield

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ABSTRACT

The effect of supplements based on *Ficus natalensis* and *Harrisonia abyssinica* foliages on intake, growth and carcass yield of tethered goats was assessed on-farm using fourty growing intact male indigenous goats. Five diets were tested, which included the control (tethering on natural pastures), tethering supplemented with molasses (CM) and the three diets whereby tethering was supplemented with molasses as well as *F. natalensis* and *H. abyssinica* as follows: *Harrisonia/* molasses (HM), *Ficus*/molasses (FM) and *Ficus/Harrisonia*/molasses (FHM). The supplements were formulated to supply crude protein (CP) and energy levels required for an average daily gain of about 50 g/day. Four farms in the same geographical location were used. Each farm had all the five diets with two goats per diet. The goats were tethered during the day (10:00–18:00 h) and the supplements offered overnight (after tethering). The dry matter (DM) intake from tethering ranged between 124 and 162 g/day, and was not affected ($P > 0.05$) the basal DM intake. However, the total DM and CP intakes were increased ($P < 0.05$) by supplementation with the browse foliages. The total DM and CP intakes were highest ($P < 0.05$) for FM (572 and 91 g/day, respectively) and FHM (638 and 102 g/day, respectively). Compared with the control, supplementation with browse foliages increased ($P < 0.05$) the average daily gain, hot carcass weight and dressing percentage by up to 37.2, 2.3 and 6%, respectively. Average daily gain was 17, 34, 45, 52 and 54 g/day for control, CM, FM, HM and FHM, respectively. The hot carcass weight was 6.9, 8.2, 8.8, 9.1 and 9.2 kg for control, CM, FM, HM and FHM, respectively. In conclusion, *Ficus natalensis* and *Harrisonia abyssinica* foliages have the potential to be used as low cost protein supplements in low-input goat feeding systems. However, there is need to establish best presentation methods of the browse foliages to the goats.

1. Introduction

Tethering goats on areas that are unsuitable for crop cultivation (road sides, marginal farrow lands, etc.) is a common way of rearing goats in eastern Uganda. The goats are normally allowed between 6 and 8 h of grazing daily. This practice limits the time of grazing as well as quantities from which goats can select their diet; thereby decreasing both the quantity and quality of feed supply to the goats. Besides, the pastures in these marginal lands are usually of poor nutritional quality. Several studies (Animut et al., 2005; Goodwin et al., 2004) have shown that where goats are allowed sufficient quantities from which to browse they are capable of selecting diets with high crude protein as well as low fiber; hence ensuring adequate feed intake and consequently good performance.

Under such conditions of limited feed supply, farmers would consider supplementing their goats with cultivated pastures or concentrates in order to improve performance. However, these options are not feasible given that arable land is increasingly becoming scarce and in many developing countries the use of concentrates is not a realistic option because of high cost and inaccessibility (Teferedegne, 2000; Katongole et al., 2012). However several studies have reported the wide availability of browse trees and shrubs such as *Acacia spp*, *Flueggea virosa, Albizia zygia, Rhuss natalensis, Ficus natalensis*, *Harrisonia abyssinica* (Tabuti and Lye, 2009; Nampanzira et al., 2015) in eastern Uganda. These browses are mainly used for firewood, construction wood, herbal medicine, but rarely used as animal feed. However, the foliages of these browse species have been reported to contain sufficient levels of protein (Yayneshet et al., 2009), they can remain green and hence maintain

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their nutritional value long in the dry season (Safari et al., 2011) and they are readily available at low or no cost. Use of these browse species would be an important strategy for improving feed supply to tethered goats in eastern Uganda, especially during the dry season when little pasture is available.

Results of one previous study (Nampanzira et al., 2016) indicated that the foliages of *Ficus natalensis* and *Harrisonia abyssinica* (widely available browse species in eastern Uganda) have a CPcontent that ranges between 110.3 and 112.2 g/kg DM, with DM degradability ranging between 632 and 743 g/kg, as well as N retention ranging between0.16 and 0.37 (as fraction of N intake). These qualities make them possible options for improving the feed quality and supply to tethered goats in eastern Uganda. Therefore, this study was conducted to evaluate the effect of supplements based on *Ficus natalensis* and *Harrisonia abyssinica* foliages on intake, growth and carcass yield of tethered indigenous goats.

2. Materials and methods

2.1. Experimental site

This study was conducted in Buyende District at 4 farmers' homes. The four farmers were selected from those who were involved in a previous ethno botanical study. The farmers were rearing goats (irrespective of herd size), willing to provide grazing land and space for the construction of structures were the supplementary diets were offered.

2.2. Experimental animals and their management

Fourty indigenous intact growing male goats 5–8 months of age and weighing between 12 and 18 kg were used. The goats were bought from local farmers. They were ear tagged, treated against intestinal parasites and sprayed with an acaricide. At the start of the feeding trial, the goats were weighed individually for three consecutive days in the morning before being tethered on pastures and the mean taken as the initial weight. At night, the goats were housed in group pens (with reference to the experimental diet allocated to them). The goats were given 10 days to adapt to the experimental conditions prior to the onset of the study. They had free access to a maclick mineral brick and drinking water in their night pens

2.3. Experimental diets

The five experimental diets (Tethering, Tethering + molasses, Tethering + F, Tethering + H and Tethering + F & H) are described in Table 1. Tethering alone without any supplement and Tethering with mollase were the control diets. The three experimental diets (Tethering + H; Tethering + F; and Tethering + H & F) were formulated to be isocaloric (equal levels of metabolisable energy) and isonitrogenous (equal levels of crude protein) targeting an average daily gain of about 50 g/day. All the 40 goats were tethered on natural pastures during the day from 10:00 to 18:00 h as was the practice in the study area. The Supplements were offered overnight (after tethering). The ingredients for the supplements were leaves of *Ficus natalensis, Harissonia abyssinica* and Molasses. The leaves of *Ficus* and *Harrisonia* were harvested daily from the existing trees and stored under roof. The molasses were bought from the open market.

Table 1
Feedstuff composition of experimental diets (%, as fed basis).

Feedstuff	Experimental diet				
	Control	CM	HM	FM	FHM
Basal diet (natural pastures)	Tethering	Tethering	Tethering	Tethering	Tethering
Supplements (% of BW, as fed basis)					
Ficus natalensis leaves (F)	–	–	–	7.0	3.5
Harissonia abyssinica leaves (H)	–	–	6.0	–	3.0
Molasses[a] (g/day) (M)	–	200	200	200	200

Control, tethering on natural pastures alone; CM, control/molasses; HM, *Harissonia*/molasses; FM, *Ficus*/molasses; FHM, *Ficus/Harissonia*/molasses.

[a] Molasses were mixed with water at a ratio of 1:2 and sprinkled on the leaves.

2.4. Experimental design

The 40 goats were divided into 8 groups of 5 goats according to body weight. One goat from each group was randomly allocated to one of the five experimental diets. Each farmer received 2 goats for each of the experimental diets. This translated into a total of 10 goats per farmer. During the day (10:00–18:00 h), each of the 4 farmers tethered each goat allowing it movement within a radius of 3m. Each goat was tied to a pole using a rope around its neck. The location of each tethered goat was changed daily. At 18:00 h the goats were untied and walked to the night pens where they were offered the supplements. Each pen housed two goats receiving the same experimental diet. The amount of supplements offered were adjusted weekly basing on the previous week's intake, so that each group of goats was offered an amount equivalent to 110% of the group's average intake of the previous week.

2.5. Data collection

2.5.1. Botanical composition of the pastures selected by the tethered goats

Direct observations method was used to determine the botanical composition of the pastures consumed by the tethered goats and their representative samples were obtained (Risenhoover, 1989). A total of 20 goats out of 40 goats were observed (5 goats per farmer) irrespective of experimental diet. The observations were done five times (every after 21days) during the study period. This translated into 100 observations. Each goat was observed for 10 min. During the observations, the observer stood in a good distance in order not to interfere with the feeding activities of the goat. The observer followed each goat, taking note of the plant (grass, shrubs trees) and morphological part consumed. Materials physically similar to those selected by the goat were clipped for botanical identification and chemical analysis. Where necessary, specimens pastures clipped were prepared and taken to Makerere University Herbarium, for botanical identification.

2.5.2. Chemical composition of consumed pastures

The different pasture species clipped from the observation of each goat were pooled by farm and weighed. This translated into 20 pasture samples. The samples were placed in plastic bags, sealed and labeled pending transportation to the laboratory for oven drying. The samples were analyzed for DM, CP and ash according to AOAC (1990). NDF, ADFand ADL according to Van Soest and Robertson (1985).

2.5.3. Voluntary intake

The voluntary intake of the pastures by the tethered goats was estimated from the total daily production of faeces (total faecal output) and digestibility.

For total faecal collection, five goats on each farm (one goat per experimental diet) were randomly selected and fitted with a faecal collection bag designed to collect all the faeces released. The bags were emptied twice a day at 10.00 and 18.00 h and the faeces from each goat weighed. The goats were given 5 days to adapt to the faecal bags. Thereafter the data was collected for 5 days and oven dried. The faecal samples collected were pooled by diet and farm. This procedure was done four times at an interval of 21 days. This translated into a total of 80 feacal samples

For digestibility of pastures, the marker/indicator method was used.

Acid Insoluble Ash (AIA) was the internal marker used. Digestibility was estimated from the concentration of AIA in the pastures and faeces. Four pasture samples (one from each farm) representative of the herbage consumed were collected for AIA analysis. The goats with the faecal bags were observed and all the pasture species consumed were clipped to get a representative sample (as described for the botanical composition study) This pasture sampling was done over the same time as the procedure for total faecal collection. The pasture samples for the five days of collection were pooled by diet and farm. This translated into a total of 80 pasture samples.

For the intake of the supplements (*Ficus* and *Harrissonia*), amounts offered as well as refusals per group pen were recorded before new feed was added. The amounts offered were adjusted on a weekly basis.

2.5.4. Average daily gain

All the goats were weighed every after 14 days for a feeding period of 113 days. The animals were weighed in the morning before they were tethered on the pastures.

2.5.5. Slaughter characteristics

At the end of 110 days, the goats were weighed for three consecutive days and the mean taken as the final body weight. All the goats were transported to a commercial abattoir (Uganda Meat Industries abattoir) for slaughter. At the abattoir, the goats were deprived of feed and water overnight, and their BW recorded just before slaughter (slaughter body weight −SBW). Immediately after slaughter, whole carcasses (kidneys removed) were weighed hot (hot carcass weight −HCW), and then chilled at 4 °C for 24 h. The gastro intestinal tract was weighed when full and then reweighed after emptying (empty gastro-intestinal tract weight). The difference in weight was regarded as the digesta weight, which was subtracted from the SBW to obtain the empty body weight (EBW).

The weight of the organs (liver, lungs and trachea, spleen, heart, diaphragm and kidneys), head (with or without horns), testicles, feet and skin was combined with that of the empty gastrointestinal tract to constitute the non-carcass weight. Dressing percentage (DP) was calculated based on the HCW and SBW. After chilling, the carcasses were graded for yield using the abattoir's 5-point grading scale (where 1 = very poor fullness with meat; 5 = excellent fullness with meat). The term 'fullness with meat' was used to refer to the level of masculinity. The carcass was then split medially and the right half of each carcass weighed. The weighed halves were then dissected with a knife into separable components of subcutaneous fat, intermuscular fat, internal fat, lean and bone. The components were weighed and their percentages of the cold half carcass weight calculated.

2.6. Statistical analysis

All data analysis was carried out using SAS (2003). As the goats were not of the same live body weight at the start of the study, all data were analyzed by ANCOVA using the PROC GLM procedure of SAS using the model: $Y_{ij} = \mu + D_i + I_j + e_{ij}$. Where Y_{ij} is the dependent variable, μ is the overall mean effect, D_i is the effect of diet, I_j is the effect of initial weight as a covariate and e_{ij} is the random error. Least-square means were compares statistically using the PDIFF procedure of SAS.

3. Results and discussion

3.1. Botanical constituents of the basal diet

The vegetation in the study area consisted mainly of shrubs and grasses. The species of shrubs, grasses, herbs and trees in the material consumed by the tethered goats are presented in Table 1. *Acacia brevispica, Lantana camara* and *Harrisonia abyssinica* were the major shrubs, while *Bracharia brizantha, Panicum maximum* and *Cyperus species* were the major grasses and *Urena lobata, Hyptis Pectinata* and *Tephrosia nana* were the major herbs consumed.

Table 2
Major botanical constituents of the pastures (basal diet) consumed by tethered goats.

Botanical name[a]	Local name (Lusoga)	Vegetation category
Acacia brevispica	*Empule*	Shrub
Bracharia brizantha	*Kifuta*	Grass
Panicum maximum	*Mukonzikonzi*	Grass
Urena lobata	*Kadantama*	Herb
Cyperus species	*Ensela*	Grass
Lantana camara	*Kapanga*	Shrub
Cynodon dactylon	*Lufafa*	Grass
Harrisonia abyssinica	*Ndalike*	Shrub
Rhus natalensis	*Kasakasaka*	Shrub
Acalypha psilostachya	*Empelele*	Shrub
Hyptis pectinata	*Kawunyawunya*	Herb
Vitex ferruginea	*Mukelemba*	Shrub
Capparis erythrocarpos	*Namukodolya*	Shrub
Combretum molle	*Mukolakola*	Tree
Euphorbia heterophylla	*Kafadanga*	Herb
Bidens pilosa	*Kalala*	Herb
Ptilotrichum elliottii	*Mugaali*	Tree
Monanthotaxis species	*Muzaimwa*	Tree
Aspilia kotschyi	*Kimwanyimwanyi*	Shrub
Abrus precantorius	*Lusitisiti*	Liana
Flueggea virosa	*Nkandwa*	Shrub
Albizia zygia	*Mulongo*	Tree

[a] Listed in the decreasing order of consumption.

3.2. Chemical composition of feedstuffs

The average chemical composition of the feedstuffs consumed during the experiment is shown in Table 2. The DM content ranged from 26 to 39.1%. The CP content was 13.9, 16.9 and 16.7% for the basal diet, *Harrisonia abyssinica* and *Ficus natalensis* leaves, respectively. The CP content for *H. abyssinica* was in the range reported by Rubanza et al. (2005) while that of *F. nantalensis* was in the range reported by Bamikole et al. (2004) and Khanal and Subba (2001) for *Ficus* species. The NDF content was 36.9, 39.2, and 24.5% for the basal diet, *F. natalensis* and *H. abyssinica,* respectively. This was in the range reported by Kendrick et al. (2009) for *F. natalensis* and about 50% lower than the value reported by Rubanza et al. (2005) for *H. abyssinica.* The lower NDF value of *H. abyssinica* reported by this study could probably be attributed to age and/or the physical composition differences of the leaves collected (Table 3).

3.3. Intake and growth characteristics

Supplementation with the browse foliages significantly increased ($P < 0.05$) the total DM intake (Table 4). However, the total DM intake from tethering was not significantly affected ($P > 0.05$). This

Table 3
Chemical composition of the basal diet (natural pastures), *Ficus natalensis* and *Harrisonia abyssinica* (means and S.D.).

	Basal diet[a]	*Ficus natalensis*	*Harrisonia abyssinica*
DM (g/kg)	331 (81)	260 (26)	391 (17)
CP (g/kg DM)	139 (20)	167 (5)	169 (41)
NDF (g/kg DM)	450 (47)	427 (31)	296 (16)
ADF (g/kg DM)	369 (40)	392 (17)	245 (10)
ADL (g/kg DM)	117 (27)	177 (25)	120 (22)
Ash (g/kg DM)	100 (26)	122 (14)	63 (4)
ME[b] (MJ/kg DM)	–	9.33	10.01

[a] All the goats were tethered on natural pastures (mainly composed of *Acacia brevispica, Bracharia brinzantha* and *Panicum maximum*) between 10:00 and 18:00 h.
[b] Source: Nampanzira (2016).

Table 4
Intake and growth characteristics of tethered indigenous goats offered supplemental diets based on *Ficus natalensis* and *Harrisonia abyssinica*.

	Experimental diets						
	Control	CM	HM	FM	FHM	SE	P-value
Supplement DM intake							
F. natalensis leaves (g/day)	–	–	–	421	292		
H. abyssinica leaves (g/day)	–	–	185	–	137		
Total DM intake (g/day)	–	–	185[b]	421[a]	429[a]	35.3	0.0001
Total CP intake (g/day)	–	–	31[b]	70[a]	72[a]	5.9	0.0001
Total ME intake (MJ/day)	–	–	1.85[b]	3.93[a]	4.10[a]	0.34	0.0003
Growth characteristics							
Initial live body weight (kg)	14.0	14.7	14.4	16.3	15.7		
Final live body weight (kg)	17.3	19.1	18.2	20.6	20.2		
Live body weight change (kg)	3.3	4.5	3.8	4.3	4.5	0.70	0.4347
Average daily gain (g/day)	30	40	34	38	40	6.2	0.4301

Control, tethering on natural pastures alone; CM, control/molasses; HM, *Harissonia*/molasses; FM, *Ficus*/molasses; FHM, *Ficus*/*Harrisonia*/molasses.
[abc]Means within the same row with different superscripts are significantly different ($P < 0.05$).

Table 5
Slaughter and carcass characteristics of tethered indigenous goats offered supplemental diets based on *Ficus natalensis* and *Harrisonia abyssinica*.

	Experimental diets						
	Control	CM	HM	FM	FHM	SE	P-value
Initial live body weight (kg)	14.0	14.7	14.4	16.3	15.7		
Slaughter body weight (kg)	16.6	19.0	17.8	19.8	19.3		
Empty body weight (kg)	14.6	17.2	16.2	18.0	17.5	1.3	0.2321
Hot carcass weight (kg)	7.1	8.0	7.6	8.8	8.0	0.67	0.3434
Non-carcass weight[a] (kg)	5.7	6.5	6.2	6.4	6.3	0.38	0.4893
Dressing percentage	43.5	42.0	42.4	44.6	41.4	2.0	0.7809
Carcass yield grade[b]	2.1	3.2	3.0	3.5	3.1	0.45	0.2344
Carcass components[c]							
Lean	68.0	65.7	65.9	68.4	64.3	2.1	0.4949
Subcutaneous fat	1.9	1.2	1.9	0.8	1.5	0.55	0.5590
Internal fat	0.2	0.7	0.9	1.1	1.4	0.42	0.2502
Bone	29.8	32.4	31.4	29.8	32.9	1.8	0.4707

Control, tethering on natural pastures alone; CM, control/molasses; HM, *Harissonia*/molasses; FM, *Ficus*/molasses; FHM, *Ficus*/*Harrisonia*/molasses.
[ab]Means within the same row with different superscripts are significantly different ($P < 0.05$).
[a] Non-carcass weight is the weight of the organs (liver, lungs and trachea, spleen, heart, diaphragm and kidneys), head (with or without horns), testicles, feet, skin and empty gastrointestinal tract.
[b] 5-point scale (1 = very poor fullness with meat; 2 = poor fullness with meat; 3 = fair fullness with meat; 4 = good fullness with meat; 5 = excellent fullness with meat).
[c] Percentage of the cold half carcass weight.

could be a direct result of more DM being available to the supplemented goats than the control group. According to Forbes (2003), intake depends on quantity of feed offered among other things. Total CP intake was also significantly improved ($P < 0.05$) by supplementation with the browse foliages. The FHM and FM groups had the highest ($P < 0.05$) total CP intake (102 and 91 g/day, respectively) followed by the HM group (56 g/day), and lowest ($P < 0.05$) for the CM and control groups (17 and 21 g/day, respectively). The low CP intake in the CM and control groups is indicative of inadequate DM intake coupled with the low CP content of the basal diet. According to Van Soest (1994), the feed value of any feedstuff is a function of both its intake and nutrient content.

Goats in all the treatment groups gained weight throughout the experimental period. Supplementation resulted in significantly higher ($P < 0.05$) live weight change than the control group (1.9 kg). Goats offered the FHM diet gained significantly more weight ($P < 0.05$) than the other groups (6.1 kg in 112 days). The live weight change was not different between the FM (5.0 kg) and HM (4.7 kg) diets. A similar trend was observed for ADG with values varying from 16.9 g/day for the control to 33.6, 51.6, 44.7 and 54.1 g/day for CM, HM, FM and FHM, respectively. This could be mainly attributed to N intake (Rothman et al., 2006). Failure to provide rumen micro-organisms with sufficient nitrogen, the most important limiting factor, impairs rumen function (McDonald et al., 2002) and causes a decreased availability of microbial protein with consequent loss of appetite (Shem et al., 2003) resulting in decreased weight change. The ADG values obtained in this study are in the range of those reported by Rubanza et al. (2007) for Small East African goats.

3.4. Carcass characteristics

The effect of the experimental diets on the carcass characteristics is summarized in Table 5. The empty body weight, non carcass weight and carcass yield grade were similar ($P > 0.05$) across the five experimental diets. The dissectible carcass components showed a similar trend. The lean and bone percentages were within the range reported by Sen et al. (2004) and Safari et al. (2011) for goats under semi-arid conditions. The subcutaneous and internal fat percentages were low compared to the other dissectible carcass components, which could be attributed to the fact that fat is a late maturing body tissue (Warriss, 2000). The goats in this study were slaughtered at 6–7 months of age; hence the low fat content.

Goats on the control experimental diet (tethered on natural pastures alone), recorded the lowest ($P < 0.05$) hot carcass weight and dressing percentage. The hot carcass weight for the control averaged 6.9 kg, compared to 8.2, 8.8, 9.1 and 9.2 kg for CM, FM, HM and FHM, respectively. These weights were in the range of the values reported by Hozza et al. (2013, 2014) for small East African goats. The hot carcass weight was similar ($P > 0.05$) across the four supplementary diets (CM, HM, FHM, and FM). A similar trend was observed for dressing percentage. The average dressing percentage for the control was 38.6% compared to 43.1, 43.7, 44.4 and 44.6% for CM, HM, FHM and FM, respectively. These dressing percentages were in the range reported by Katongole et al. (2009) and Safari et al. (2011) for indigenous goats. The low hot carcass weight and dressing percentage exhibited by the control group could be attributed to their low growth rate caused by the low intake of both N and readily available energy. Supplementation with the browse foliages (*Ficus natalensis* and *Harrisonia abyssinica*) increased the N intake by animals (Rothman et al., 2006), while sugarcane molasses increased the rapidly available energy intake (Paterson-Beedle et al., 2000). An efficient microbial protein synthesis in the rumen requires a good supply of rapidly available energy in the form of water soluble carbohydrates (Beever, 1993), which was not the case with the control goats (tethered on natural pastures alone). Under natural pastures alone, the rumen micro-organisms have to rely on the structural carbohydrates (cellulose and hemicellulose) whose breakdown rate is much slower (Lee et al., 2003); consequently resulting in the loss of ammonia from the rumen and hence a reduction in efficiency of microbial protein synthesis. This therefore resulted into reduced weight gain and hence the low hot carcass weight and dressing percentage.

4. Conclusions

Supplementing tethered indigenous goats with Ficus natalensis and Harrisonia abyssinica foliages did not affect the basal DM intake but significantly increased the total DM and CP intakes with a positive influence on live weight change, hot carcass weights and dressing percentage. This is attributed to the good acceptability and relatively high CP content of the browse foliages. These browse foliages can therefore be used as low cost protein supplements to low quality feeds. However, there is need for further studies to determine the best presentation method of the browse foliages maximum intake by tethered goats.

Conflict of interests

No conflict of interest.

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