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Performance and cost benefit of variable inclusion levels of shea nut meal in the diet of growing sheep

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Abstract
Poor forages are the drivers to poor livestock performance. Concentrates or fats can improve nutrient utilization in forages if mixed together. However, conventional concentrates are expensive and in demand for use in pig and poultry feeds. This study investigated the nutrient composition of shea nut meal (SNM) and its effect on the performance of growing sheep when added at different inclusion levels. Fifteen ewes weighing 25±0.8kg were grouped into five (N = 3) and assigned five diets containing 0%, 5%, 10%, 15% and 20% SNM in a completely randomized design. Diets were analyzed for chemical composition and data on intake, nutrient digestibility, average daily gain (ADG), feed conversion ratio (FCR) and cost of feed per kg gain were computed. Results obtained showed SNM (g/kgDM) contains 302 (ADF), 589 (NDF), 172 (CP), 304 (EE), 120 (total tannins) and 25 (ME) and improved 395 (ADF), 649 (NDF), 150 CP, 304 EE, and 18.3 ME in diets. Feed intake was improved at 5% but was not different (p>0.05) from 0% but also declined with increasing inclusion of 10%, 15% and 20%. Nutrient digestibility was improved (p<0.05) except for EE. Average daily gain was also improved and was higher at (5%) and lower at (0%) (p<0.05). The best FCR was observed at (20%) but did not differ in all SNM diets (p>0.05). The cost of feed per kg gain (KES/kg) reduced with increasing SNM inclusion levels. It was concluded that SNM is a possible cheaper energy and protein source for growing sheep. It improved nutrients in diets, intake at 5%, nutrient digestibility, ADG, FCR and reduced the cost of feed per kg gain in sheep feeding.

Keywords: Average daily gain, cost of feed/kg gain, feed conversion ratio, feed intake, nutrient digestibility.

Introduction
Feed scarcity in Sub-Saharan Africa is increasingly evident as even wastes from agricultural harvests, agricultural product processing and manufacturing are becoming very costly [11]. A majority of livestock farmers are low input ranchers who depend entirely on natural forages. Natural forages have several limitations; they become scarce during the dry season and highly lignified as they age thus negatively impacting on the nutrient content, intake, digestibility and animal performance [16]. Improvement attempts on natural forages are also constrained by high input costs that negatively impact on farmer net profit and the costs to benefits are never immediate or obvious [17]. Supplementation of ruminants fed poor forages with concentrates or fats is reported to modulate the rumen therefore improving its efficiency [25, 27]. However, concentrates are as well scarce as they are demanded in non-ruminant feeds such as pigs and poultry and their use in ruminant feed is also considered uneconomical. Identification of non-conventional ingredient sources especially from non-competitive human edible products can bridge this gap and also promote a sustainable food system [24]. The Shea nut tree (*Vitellaria paradoxa*) is a deciduous tree that is native to Africa. The trees self-plant and are later farmer-selected in a grassland system. It is estimated that the tree's natural range extends across 21 African countries from the eastern part of Senegal to Gambia and to the high plateaus of East Africa into North Eastern Uganda, forming almost an unbreakable belt of 6,000 km long, and an average of 500 km wide [19, 16]. In Uganda, the trees are widely distributed in the northern, north eastern, and west Nile regions of the country [19]. Shea nut trees produce nuts that are usually processed to produce Shea butter and Shea nut meal as the waste [19, 10].

Shea butter composition is reported to be almost similar to coconut fat [9] and thus its use as a replacer for coconut butter in the cosmetic, chocolate, soap or food industry is increasing [19, 10]. In the recent past, there has been an increase in harvest, processing and export of the butter fat [19, 16, 7] which has made the waste (Shea nut meal) readily available. This study therefore aimed to investigate the nutrient composition and the impact of increasing Shea nut meal on diet composition, intake, nutrient digestibility, growth performance and cost benefit ratio when fed to growing sheep on Rhodes grass hay (*Chloris gayana)* and maize bran basal diets.

Materials and Methods

Study location

The study was conducted at Tatton Agriculture Park (TAP) of Egerton University, Njoro, Kenya. The University coordinates are: 0°22'11.0" S, 35°55'58.0" E. (Latitude:-0.369734; Longitude: 35.932779) (www.egerton.ac.ke). At the time of the experiment, the region was receiving a bimodal rain pattern ranging between 1000 to 1200 mm with variable temperatures between 17 and 22 °C (Egerton University weather station unpublished data 2021).

Experimental animals and housing

Fifteen (15) growing Corriedale ewe WEANERS at five months of age with an average weight of 25±0.8kg were obtained from Ngogongeri farm of Egerton University. They were dewormed with albendazole 10% and transferred to TAP. They were randomly grouped into five (n=3), individually housed in slated iron roofed pens and allocated to five diets.

Experimental diets and feeding

Shea nut meal was the supplement in this experiment. The Shea nut kernels were sourced from Katakwii district in Uganda. The kernels were mechanically processed by ram pressing to obtain the butter then the meal. The latter was supplemented at four levels to the basal diet. The formulated diets consisted of (T_1): 70% Rhodes grass hay and 30% maize bran to constitute the basal diet or Control. (T_2) basal diet + 5% sheanut meal (SNM), (T_3) basal diet + 10% SNM, (T_4) basal diet + 15% SNM and (T_5) basal diet + 20% SNM. Animals were fed at 3% (750g) of their individual live body weight plus mineral supplement and water offered *ad libitum*. An adaptation period of 7 days was allowed during which time all animals were fed the basal diet followed by 14 days back-grounding period, which was used to establish the feed: weight constant for individual animals' intake (preliminary period), followed by data collection period that lasted for 14 weeks. Composition of experimental diets is presented in the table 1.

Table 1: Composition of experimental diets (g)

Ingredient (% of DM)	T_1 (0%)	T_2 (5%)	T_3 (10%)	T_4 (15%)	T_5 (20%)
Rhodes hay (g)	525	525	525	525	525
Maize bran (g)	225	187	150	112	75
Shea nut meal (g)	0	38	75	113	150

T_1 = Treatment 1, T_2 = Treatment 2, T_3 = Treatment 3, T_4 = Treatment 4 and T_5 = Treatment 5

Chemical analysis of feed ingredients and diets

Feed ingredients were ground to 1-mm particle size using Wiley mill and sub-samples drawn to formulate diets. Dry matter, ash, and ether extract were analyzed according to the Association of Official Analytical Chemists procedure [1]. Nitrogen was analyzed using the Kjeldahl method and percentage CP calculated as N x 6.25. Neutral detergent fibre (NDF) and acid detergent fiber (ADF) were determined as per the method described by [26] and total tannins were analyzed using procedure by [21].

Feed intake data/sample collection and chemical analysis

On the fifth week after the adaptation period, data on feed refusals from individual animals were collected for 7 days and measured on a daily basis at 08:00hr before trough cleaning and offer of new feed. The feed refusal of 7 days collection was thoroughly mixed and sub-samples were drawn; they were oven dried at 60 °C to a constant weight. The samples were ground to pass through 1mm sieve and analyzed for chemical composition according to the Association of Official Analytical Chemists procedure [1].

Faecal sample/data collection and analysis

Animals were harnessed with polythene bags on the fourth week in preparation for faecal matter collection that started in the fifth week. The bags were harnessed to the animals with the help of straps attached to the bags and to the animal by wrapping through the animal both around the chest and between the fore limbs. Faecal bags were emptied in to a pre-weighed bucket every morning and the bucket with feces reweighed to obtain faecal weight after the weight of the bucket subtracted. Individual faecals were thereafter thoroughly mixed and approximately 10% of the daily faecal collection from each animal sampled in to the polythene bags and stored in a deep freezer at -20 °C. At the end of the 14 days collection period, the sampled portions of the faeces from each animals' faeces were thawed, pooled in accordance to individual groups, thoroughly mixed and samples were taken in duplicates, dried in (forced air oven) at 60 °C to a constant weight. The faecal samples were then ground to pass through 1mm sieve and analyzed for chemical composition according to the Association of Official Analytical Chemists procedure [1]. Nutrient digestibility was then calculated from the data collected above as per the following method:

Apparent nutrient digestibility =

$$100\ X \frac{Nutrient\ intake - Nutrient\ excreted}{Nutrient\ intake}$$

Weight gain and cost: benefit analysis (CBR)

Initial weights for the animals were measured at the end of the adaptation period. It was then followed by bi-weekly weighing i.e. (at two weeks' interval as stabilization period), for 14 weeks, each round weighed in the morning at the same time, before feeding to determine weight gain. The cost to benefit ratio of different inclusion levels of SNM was calculated based on the economics of production and the prevailing market prices of the feed ingredients during the experimental time, with the US dollar exchange rate for Kenya shillings (KES) pegged at $ 1: KES 100. The following parameters were used to deduce CBR;

Live weight gain (LWG) =
$$Final\ weight - Initial\ weight$$

$$\text{Average daily gain (ADG)} = \frac{Live\ weight\ gain}{Number\ of\ days\ fed}$$

Feed conversion ratio (FCR) = $\frac{Total\ feed\ consumed}{Live\ weight\ gain}$

Cost of feeding per ewe =

$$Total\ feed\ consumed\ X\ Cost\ of\ feed$$

Cost of feed/kg gain = $\frac{Cost\ of\ feeding\ per\ ewe}{Live\ weight\ gain}$

Statistical analysis

Data were analyzed using the general linear model of statistical analysis system [23] version 9.0. Significant means at (p<0.05) were separated using least significance difference and sources of variation were initial animal weight, treatment diets and error.

Results and Discussion

Chemical composition of feed ingredients and experimental diets

The nutrient composition of feed ingredients and formulated diets are as presented in Table 2. Shea nut meal (g/kgDM) has considerable nutrients as indicated: ADF (302), NDF (589), CP (172), EE (304) and ME (25). The nutrient composition in SNM in this study were substantially higher from those reported by [5, 14, 18] but were within the range with what [8] reported except for ash and ME which were slightly higher. These differences may possibly be attributed to environmental, nutritional and processing differences as the meal from this study was mechanically processed and was observed to have high residual fat. SNM inclusion increased ADF, NDF, CP, EE, and ME in the diets (P<0.05). The increase could be because the meal is high in the listed nutrients. This result concurs with; [5, 13, 14; 28], who also reported nutrient improvement with SNM. SNM can thus be recommended as a nutrient source especially of energy and protein in diets of sheep.

Table 2: Chemical composition of feed ingredients and experimental diets in (g/kg DM)

Ingredients	Parameters								
	DM	Ash	ADF	NDF	CP	EE	Tannins	ME	CF
Shea nut meal	905	56	302	589	172	304	120	25	-
Maize bran	943	252	104	365	131	37	-	15	-
Rhodes hay	919	103	418	713	113	14	-	17	-
Treatments									
T_1 (0%)	929^{a}	142^{a}	376^{c}	613^{d}	120^{c}	30.8^{e}	0.00^{d}	15.6^{d}	294^{a}
T_2 (5%)	926^{ab}	125^{b}	383^{b}	623^{c}	138^{b}	64.8^{d}	4.00^{d}	16.6^{b}	285^{ab}
T_3 (10%)	916^{ab}	111^{c}	390^{a}	639^{b}	141^{ab}	83.2^{c}	6.78^{c}	17.2^{b}	283^{b}
T_4 (15%)	913^{ab}	101^{d}	390^{a}	641^{ab}	149^{a}	102^{b}	8.17^{b}	17.9^{a}	278^{b}
T_5 (20%)	910^{b}	88.5^{e}	395^{a}	649^{a}	150^{a}	134^{a}	9.36^{a}	18.3^{a}	279^{b}
SEM	5.343	2.1794	1.6465	2.5210	3.2110	0.5411	0.5051	0.1754	3.0073

SEM, standard error of the means, ^{abcde} Means within the column with different letter superscripts are different at (p<0.05). DM = Dry mater, ADF = Acid detergent fiber, NDF = Neutral detergent fiber, CP = Crude protein, EE = Ether extract, ME = Metabolizable energy, CF = Crude fiber & - Not determined.

Feed intake and nutrient digestibility (%) of Rhodes grass hay and maize bran basal diets with increasing levels of SNM in growing sheep.

Shea nut meal inclusion in sheep diets had both positive and negative impacts on dry matter intake (DMI) and nutrient digestibility. Dry matter intake was higher at 5% but was not different (p>0.05) from the control (0%). DMI then decreased (p<0.05) at high SNM inclusion of 15% and 20%. The increase in DMI at 5% can be attributed to low fat and tannin levels in the diet and also to improvements in the diet palatability, reduced dustiness and improved consistency in the feed as a result of moderate SNM inclusion. These findings agree with [30] who reported that intake improved at low shea butter inclusion but disagree with [13] who reported that intake increased with increasing SNM inclusion. The variance could be attributed to the difference in SNM processing techniques employed that might have impacted on SNM compositions and subsequently the formulated diets. The decline in DMI with SNM increased inclusion beyond 5% could be attributed to increase in fat and tannins content in diets beyond tolerable limits. The results concur with [30;18] who reported that beyond 100g/kg shea butter and 25% SNM inclusions respectively, depression in feed intake was observed in sheep respectively. Nutrient digestibility improved with SNM inclusion though was variable, it was high at 5% and 10% compared to the control (0%) (p<0.05) and declined at 15% and 20% inclusion. Improved nutrient digestibility can be attributed to the increase in protein and energy in the diet and to the rumen microbes, enhancing the rumen micro environment. A high nutrient digestibility observed at 5% and 10% compared to 15% and 20% can be attributed to relatively moderate fat and tannins that had minimal negative impact on digestibility. The findings agree with [13, 18] who reported improvement in digestibility with increased SNM except when inclusion was beyond 25%. The decline on the other hand with increased SNM at 15% 1nd 20% could be attributed to the high fat and tannins in the diets beyond microbial activity favorable limits. High tannin levels are reported to reduce feed palatability and cause irritation of the membrane in the mouth. Tannins also bind proteins, enzymes and microbial cells, thus interrupting with nutrient digestion [8, 18; 12]. High fat levels beyond 7% conversely are believed to decrease feed intake due to negative digestibility resulting in the disruption of the normal rumen function reported to reduce DM intake [2, 3]. Data on DMI and nutrient digestibility is presented in Table 3.

Table 3: Feed intake (g) and nutrient digestibility (%) of sheep fed Rhodes grass hay and maize bran basal diets supplemented with SNM

Parameters	Diets					SEM
	T_1	T_2	T_3	T_4	T_5	
Feed Intake (g/d)						
Concentrate mixture	225^a	225^a	213^a	192^b	181^b	5
Hay	533^a	611^a	364^b	264^b	243^b	47.9
Total DMI	758^a	836^a	577^b	456^{bc}	424^c	47
Digestibility (%)						
DM	60.25^e	82.45^b	85.86^a	71.44^c	65.70^d	0.8575
Protein	93.26^a	98.21^a	97.06^a	94.44^a	93.23^a	1.6995
ADF	45.27^{bc}	65.78^a	50.17^b	45.91^{cd}	45.19^{cb}	1.5619
NDF	44.16^b	52.76^a	52.71^a	42.17^{bc}	41.33^c	0.8035
EE	99.99^a	99.99^a	99.88^b	99.75^c	98.68^d	0.0139

SEM, standard error of the means,

^{abcde} Means within the rows with different letter superscripts are different at ($p<0.05$).

DM=Dry matter, ADF=Acid detergent fiber, NDF=Neutral detergent fiber, EE=Ether extract

Performance of Corriedale ewes fed Rhodes grass hay and maize bran basal diets with increasing levels of SNM supplementation

Table 4 contains the summary Results of sheep performance fed increasing SNM levels. Average daily gains (ADG) improved with SNM inclusion. Average daily gain range was (133-76.9g), it was higher at 5% (133g) and lower at 0% (76.9g) ($p<0.05$). The high ADG in SNM fed groups can be attributed to the improvement in feed intake for 5% and high energy levels in SNM diets for 10%, 15% and 20% as a result of increased fats that improved calorific supply despite the low DMI. These findings agree with [13] who reported improvement in DMI in sheep fed SNM diets. Final weights range was (32.9-38.7kg) the weights were high for (5%) and lowest for 0% but were not ($p>0.05$) different across diets. The unsignificant difference in final weights is possible as all diets were seemingly poor. Rhodes grass hay is a very low-quality ingredient and had contribution of 70% in all diets. The FCR range was (4.77-9.89 DMI/kg gain). It improved with increased SNM inclusion. It was lower at 15% (4.77 DMI/kg gain) and higher for 0% (9.89 DMI/kg gain). Improvement in FCR with increased SNM inclusion in diets can be accredited to increased improvement in protein and energy levels of diets with SNM due to its high nutrients that subsequently improved the nutrient balance. Fat is an excellent source of energy and thus is reported to improve the feed energy value [3]. Fats of good fatty acid profile are also believed to modulate the rumen by maintaining optimum pH levels, improvement of acetate propionate ratio and detoxification of protozoa with subsequent reduction in methane production, this in turn results in improved feed conversion ratio and growth performance [22, 4; 20]. The presence of tannins as well must have played a role in improved performance as low tannins of 5-10kg^{-1} DM are believed improve rumen efficiency and general performance [12], and the tannins supply in this study were within acceptable range.

Table 4. Performance of Corriedale ewe fed Rhodes grass hay and maize bran basal diets with increasing levels of SNM

Parameters	Treatments					SEM
	T_1	T_2	T_3	T_4	T_5	
Initial weight (kg)	25.4^a	25.7^a	25.9^a	25.3^a	25.2^a	2.345
Final weight (kg)	32.9^a	38.7^a	35.6^a	34.7^a	34.5^a	2.930
Average daily gain (g)	76.9^b	133^a	99.3^b	96.3^{ab}	94.9^{ab}	15.414
Feed conversion ratio (DMI/kg gain)	9.89^a	6.66^b	5.86^b	4.77^b	4.97^b	0.7785

^{ab} Means within rows with different letter superscripts are different at ($p<0.05$). T_1 = (0%), T_2 = (5%), T_3 = (10%), T_4 = 15%, T_5 = (20%), SEM = Standard error of the means

Cost: benefit analysis of increasing inclusion of SNM to sheep fed Rhodes grass hay and maize bran basal diets

The cost/kg formulated feed increased with increased SNM inclusion ($p<0.05$) and was in a range of (15.56-16.94 KES). A lower cost was observed in 0% (15.56 KES) which was different from 20% (16.94 KES) ($p<0.05$). The increase in cost with SNM increasing inclusion in diets could be because the shea nuts were sourced almost off season therefore SNM was overpriced for this study. The cost of feeding per ewe however reduced with increasing SNM inclusion in diets. This was attributed to the reduction in total feed consumption with SNM increasing inclusion. Consumption range was (41.5 -74.3kg/ewe). It was higher for 5% (74.3kg) and lower for 20% (41.5) ($p<0.05$). Live weight/kg gain range was (7.53-13 kg). It was higher for 5% (13kg) and lower for 0% (7.53kg) ($p>0.05$). The cost of feed/kg gain ranged (78.7-154 KES/kg). It was lower in SNM diets compared to the control ($p<0.05$), with the lowest recorded in 15% (78.7 KES/kg). The reduction in the total feed consumption and hence the cost of feeding per ewe can be attributed to the energy rich SNM diets that compensated for low consumption yet bettered live weight gain. The results concur with [30] who reported a lowered cost of feed /sheep fed when shea butter fat was fed at 100 g/kg compared to when it was fed at 50 g/kg and in the control group. SNM enhances protein, NDF, ADF, fats and energy. This must have caused a positive nutrient utilization benefit plus tannins bounding proteins in the rumen hence making nutrients much more available in the abomasum and thus bettered performance [30, 5, 15]. The summary of results obtained are presented in Table 5.

Table 5: Cost: benefit analysis of increasing SNM in diets of growing sheep fed Rhodes grass hay and maize bran basal diets

Parameters	Inclusion levels					SEM
	T_1	T_2	T_3	T_4	T_5	
Cost /kg/feed (KES)	15.6^e	15.9^d	16.2^c	16.5^b	16.9^a	0.000
Total feed consumed (kg)	74.3^a	81.9^a	56.5^b	44.7^{bc}	41.5^c	4.627
Cost of feeding/Ewe (KES)	1156^a	1308^a	917^b	739^b	704^b	74.056
Live weight gain (kg)	7.53^b	13.0^a	9.73^{ab}	9.43^{ab}	9.30^{ab}	1.5106
Cost of feed/kg gain (KES/kg)	154^a	107^b	95.1^b	78.7^b	84.3^b	12.835

^{abcde} Means within the rows with different letter superscripts are different at (p<0.05),
LSD = least significant difference. T_1= (0%), T_2 = (5%), T_3 = (10%), T_4 =15%, T_5 = (20%), SEM =Standard error of the means.

Conclusion

It is concluded that shea nut meal is a potential protein and energy source for ruminant feeds that improves digestibility, growth performance, feed conversion ratio and cost benefit ratio when fed to sheep. The best intake and performance were observed at 5% but the cost: benefit ratio improved with increased inclusion and was best observed at 20%.

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Disclosure Statement

The authors report no potential conflict in the publication of the manuscript.

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