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The Effect of *Momordica foetida* Inclusion on Feed Intake, Digestibility, Growth Performance and Economic Efficiency of Bonga Sheep Fed on *Desho* (*Pedicellatium glocifolium*) Grass Hay as a Basal Diet

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Simple Summary: To minimize feed costs, *Momordica foetida* may be utilized as a source of protein feed for ruminants. We evaluated the effect of replacing noug seed (*Guizotia abyssinica*) cake with *Momordica foetida* leaves to improve sheep's feed intake, nutrient digestibility, and body weight. *Momordica foetida* leaves a promising protein supplement in the tropics and subtropics.

Abstract: This experiment examined the effect of feeding graded levels of *Momordica foetida* leaf (MFL) as a substitute for Noug Seed Cake (NSC) on feed intake, digestibility, growth performance, and economic efficiency. Forty-two yearling lambs (16.1±0.6 kg) were randomly allotted to six dietary treatment groups for 90 days feeding trial followed by ten days digestibility trial. Treatments were T1(Control) = adlibitum PG (*Pennisetum glaucifolium*) + 449.3gm WB (Wheat Bran), T2 = 449.3gm WB + 100% MFL; T3 = 449.3gm WB + 75% MFL + 25% NSC; T4 = 449.3gm WB + 50% MFL + 50% NSC; T5 = 449.3gm WB + 25% MFL + 75% NSC; T6 = PG + 449.3gm WB + 0% MFL + 100% NSC. Data were analyzed using SAS's General Linear Model (GLM) procedures (version 9.4, 2019). The result indicates that the increasing level of MFL had no significant effect on basal dry matter intake. The apparent digestibility of DM was higher (P<0.001) in T1 (60.5%) and T6 (62.5%); a higher (P<0.001) average daily gain was recorded for animals in T6 (171.0g/d). The cost-benefit analysis revealed that T5 has a good and optimum final body weight gain (30.5kg), 765.5 ET/head total return, and 381.1 ETB/head net return. It was concluded that 25% inclusion of MFL in the diet increases nutrient intake, weight gain and economic efficiency in Bonga sheep.

Keywords: *Momordica foetida*; *Guizotia abyssinica*; *Pedicellatium glocifolium*; dry matter intake; weight gain; Bonga sheep

1. Introduction

Feeding the agro-industrial by-products such as oil seed cakes and brans as supplements to low-quality basal diets by smallholder farmers is being challenged by high prices and scarcity due to the high demand for such feeds to the urban and peri-urban development of commercial farms [1]. On the other hand, multipurpose trees that are available year-round in the tropics and require low agronomic inputs could improve the nutritive value of low-quality basal diets.

In some African countries, *Momordica* spp is widely cultivated [2] and commercially grown for its nutritional value [3]. The fruits, leafy shoots, and ripe seeds are utilized as vegetables [4]. *Momordica foetida* leaf (MFT) is rich in energy, protein, fiber, calcium, iron, magnesium, zinc, β-carotene, foliate, and ascorbic acid [5, 6; 7]. The leaves are used as fodder and protein supplements [8], the dominant local forage at forest edges and farmlands with large biomass in the study area.

Hence, MFL under smallholder farming can become a cheaper feed alternative than agro-industrial by-products. Therefore, the current experiment assessed the effect of substituting MFL for

NSC on feed intake, digestibility, BLW change, and economic efficiency of Bonga sheep fed a basal grass hay diet. We hypothesized that the positive attributes of MFL, when replaced with a NSC, would improve the performance of sheep. To test this hypothesis, we examined the effect of replacing MFL with NSC offered on dry matter intake (DMI), average daily gain (ADG), feed digestibility, and economic efficiency of Bonga sheep.

2. Materials and Methods

2.1. Description of the study area

The experiment was conducted at the Modiyo sheep research sub-station located at 7° 26′ N latitude and 36° 47′ E longitude with an elevation of 1867 masl. Based on the eight (8) years of data, the average daily temperatures are 14 and 17◦C, respectively. The average annual rainfall ranges were from 1600 to 2200 mm. The primary rainy season of the area extends from April to November, covering more than eight months of the year. The study area is characterized by clay loam soil and dominated by a mixed crop-livestock production system [9]

Management of animals and experimental design conducted. Forty-two yearlings' male intact lambs with initial body weight (IBW) of 16.8 ± 1.9 kg were purchased from Boka-Shuta community-based breeding cooperatives. They were housed individually in 2.0m × 1m pens and randomly assigned into six dietary treatment groups with seven replications in a completely randomized block experimental design. The sheep were allowed 14 days of adaptation. Before the experiment, sheep were treated against internal and external parasites with albendazole and diazinon.

The sheep were blocked by initial body weight and assigned to six treatment groups in a completely randomized block design. Treatments; T1(Control)=adlibitum PG + 449.3gm WB, T2 = 449.3gm WB + 100% MFL; T3 = 449.3gm WB + 75% MFL + 25% NSC; T4 = 449.3gm WB + 50% MFL + 50% NSC; T5 = 449.3gm WB + 25% MFL + 75% NSC; T6 = PG + 449.3gm WB + 0% MFL + 100% NSC as indicated in Table 1.

Table 1. Chemical composition of feed used in the experiments.

Chemical composition of experimental feeds(%DM)									
Feeds	**DM**	**OM**	**CP**	**NDF**	**ADF**	**ADL**	**Ash**	**ME**	IVOMD
PGH	92.0	85.0	7.0	69.2	44.9	5.4	13.8	5.9	50.7
MFL	95.5	81.2	28.9	20.1	15.7	6.7	14.3	9.5	71.5
WB	90.4	95.3	16.1	40.6	15.5	3.3	4.5	9.4	82.5
NSC	91.6	90.4	33.2	9.5	34.7	10.7	4.5	10.3	90.3
CM	92.0	89.0	22.6	36.2	21.8	3.0	5.5	10.9	78.0
Treatment Diets									
T1	93.0	89.9	7.2	68.4	46.9	6.5	15.0	7.1	49.8
T2	92.4	82.9	24.8	25.3	20.9	6.0	14.0	9.5	70.4
T3	92.4	84.8	23.6	27.3	21.5	6.6	13.3	9.3	69.3
T4	92.5	84.4	21.3	31.0	22.9	6.4	14.4	8.9	66.3
T5	92.8	86.6	18.8	37.2	24.1	6.1	11.0	8.5	61.7
T6	92.6	87.1	16.1	38.9	22.7	6.6	10.6	7.8	56.5
P- value	0.871	0.0001	<.0001	<.0001	<.0001	0.0459	<.0001	<.0001	<.0001
SEM	0.40	0.89	0.48	0.61	0.48	0.48	0.46	0.19	0.55

PGH-*Pennisetum glaucifolium* hay, MFL- *Momordica foetida* Leaf, CM-concentrate mix, WB- Wheat bran, NSC-Noug seed cake, DM-dry matter, OM-Organic matter, CP-crude protein, NDF-neutral detergent fibre, ADF-acid detergent fibre, ADL= acid detergent lignin, ME-metabolizable energy, IVOMD – in-vitro organic matter digestibility.

2.2. Chemical analysis

The DM, organic matter (OM), crude protein (CP), and ash were determined according to AOAC (2005). CP content was measured by the Kjeldahl method as N*6.25. The content of neutral detergent fiber (NDF), acid detergent fiber (ADF) and acid detergent lignin (ADL) was determined according to Van Soest and Robertson.

2.3. Measurements

2.3.1. Feed intake and conversion efficiency

The supplements were offered in two equal portions at 8:00 h and 16:00 h daily, and the experimental sheep had free access to mineral block and water. Daily feed intake measurements were made for the 90 days of the feeding trial. The daily feed intake of individual animals was calculated as follows:

Feed intake (g) = Amount of feed offered (g) – Amount of feed refused (g).

The metabolizable energy (ME) intake of experimental animals was estimated from its digestible organic matter intake (DOMI) by using the formula,

ME (MJ/kg DM) = DOMI × 0.0157.

Where DOMI = g digestible OM/ kg DM.

Feed conversion efficiency was measured using the formula.

$$\text{Feed conversion efficiency} = \frac{\text{Average daily live weight gain (g)}}{\text{Average daily feed intake (g)}}$$

2.3.2. Feed digestibility

The digestibility trial was conducted for seven days after ninety days of experimental feed. Faeces were collected and weighed every morning for each animal before giving feed or water. The daily collected faces from each animal were weighed and mixed thoroughly, and 20% were sampled and kept in airtight plastic containers and stored at −20 °C up to the completion of the digestibility trial. The apparent digestibility percentage of DM, CP, Ash, NDF, ADF, and ADL [11].

$$\text{Digestibility (\%)} = \frac{\text{Nutrient intake} - \text{Nutrient excreted in faeces}}{\text{Nutrient intake}} * 100$$

2.3.3. Live weight change and daily gain

The live weight of each animal was taken every 15 days at intervals in the morning before the provision of feed and water. The live weight gain has been calculated as ted the difference between the final body weight and the initial live weights of the bucks. Average daily gain (ADG) was calculated as follows:

$$\text{ADG(kg/d)} = \frac{\text{Final body weight (Kg)} - \text{Initial live weight (Kg)}}{\text{No.of feeding days}} * 100$$

2.3.4. Partial budget analysis

The partial budget analysis was taken to determine the cost-benefit (profitability) analysis supplementation of different proportions of MFL instead of concentrate mix. At the end of the experiment, the selling price of each experimental sheep was estimated by three experienced local sheep dealers. The average of those three estimation prices was taken. The total returns (TR) were determined by calculating the difference between the estimated selling prices and purchasing price of the experimental goat. Net return (NR) was calculated as follows.

NR = TR − TVC

The change in net return (ΔNR) was calculated as the difference between the change in total return (ΔTR) and the change in total variable costs (ΔTVC).

ΔNR = ΔTR – ΔTVC

2.4. Statistical analysis

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The data collected on feed intake, digestibility, and body weight gain were subjected to the analysis of variance (ANOVA) model for RCBD using Statistical Analysis System Software (SAS version 9.1). When the differences in treatment means were significant at the probability level of P<0.05, the means were compared using the Least significant difference (LSD) test.

The statistical model used was:

$Y_{ij} = \mu + T_i + B_j + e_{ij}$

Where;

Y_{ij} = the dependent variable, μ =overall mean,

T_i =effect of treatment, and B_j=block effect e_{ij} =random error.

3. Results

3.1. Chemical composition of treatment feeds

The chemical composition of the feeds used in the present study is specified in Table 1. The CP content of the hay refusals was decreased while the content of NDF, ADF, and ADL increased compared to the hay offered.

3.2. Feed and nutrient intake

As indicated in Table 2, sheep supplemented with 201.9 g NSC and 83g MFL+151.4 g NSC had the highest ADL intake values than sheep supplemented with 166.1gMFL+100.9gNSC, 249gMFL+50.5gNSC, and 332.1gMFL. Contrary to the result of NDF and ADL intake, ADF intake was non-significant (P > 0.05) among the groups.

Table 2. Daily dry matter and nutrient intake of Bonga sheep fed PG hay and supplemented with different levels of MFL to replace NSC.

Parameters(g/kg/d)	T1	T2	T3	T4	T5	T6	SEM	P
Dry matter intake								
Basal DMI	547.22^{a}	525.75^{a}	531.36^{a}	541.17^{a}	524.36^{a}	540.57^{a}	21.83	ns
Supplement DMI	-	300.35^{b}	325.38^{ab}	319.78^{ab}	348.38^{a}	358.70^{a}	14.83	***
Total DMI	524.9^{d}	825.5^{c}	857.0^{bc}	862.2^{abc}	872.6^{ab}	900.7^{a}	13.27	***
DMI (%BW)	1.7^{e}	4.7^{a}	4.3^{b}	3.8^{c}	3.2^{d}	3.0^{d}	0.06	***
Nutrient intake								
OMI	491.82^{e}	685.28^{d}	726.98^{c}	726.60^{c}	755.77^{b}	783.20^{a}	21.6	***
CPI	39.42^{e}	105.01^{d}	110.74^{c}	111.85^{c}	125.28^{b}	134.64^{a}	0.78	***
NDFI	404.9^{a}	209.38^{e}	234.12^{d}	235.00^{d}	324.74^{c}	349.77^{b}	0.68	***
ADFI	256.57^{a}	172.67^{e}	184.32^{d}	197.48^{c}	204.41^{b}	204.17^{b}	0.82	***
ADLI	35.6^{d}	49.6^{c}	56.6^{c}	55.1^{b}	49.8^{a}	59.2^{a}	0.87	***
MEI	8.9^{bc}	8.5^{c}	9.7^{a}	9.6^{a}	9.2^{ab}	9.14^{abc}	0.20	***

a,b,c,d,e Mean values within a row with different superscripts are highly significantly different at *** = (p<0.001), significant at ** = (p<0.01); DMI-dry matter intake, SEM-standard error of mean, SL-significance level, %BW-percent of body weight, OMI-Organic matter intake, CPI-crude protein intake, NDFI-neutral detergent fiber intake, ADFI-acid detergent fibre intake, ADLI= acid detergent lignin intake, MEI-metabolizable energy intake, ns non-significant;.\

3.3. Dry matter and nutrients digestibility

The apparent DM and nutrient digestibility percentages of experimental feeds are shown in Table 3. Apparent DM digestibility recorded was highest in groups supplemented 201.9 g NSC (P < 0.05) but statically similar with groups supplemented 83g MFL+151.4 g NSC. The apparent CP digestibility in groups supplemented 201.9 g NSC and 83g MFL+151.4 g NSC was higher (P < 0.001) than 166.1gMFL+100.9gNSC and 249gMFL+50.5gNSC.

Table 3. Body weight gain parameters of Bonga sheep fed on PG hay and replacement of noug seed cake content with different levels of MFL.

Parameter	T1	T2	T3	T4	T5	T6	SEM	SL
DMD	60.5^{b}	61.3^{ab}	61.6^{ab}	61.6^{ab}	61.0^{ab}	62.5^{a}	0.56	***
CPD	60.8^{d}	68.4^{c}	$69.8b^{c}$	69.7^{bc}	71.0^{ab}	72.6^{a}	0.58	***
NDFD	53.2^{b}	53.2^{b}	53.7^{b}	54.1^{b}	54.3^{b}	58.3^{ab}	0.5	ns
ADFD	46.2^{a}	45.6^{a}	41.4^{b}	41.9^{b}	42.35^{b}	41.7^{b}	0.7	ns

a, b, c, d, e Mean values within a row with different superscripts are highly significant different at *** = ($p<0.001$); IBW=Initial body weight, FBW=Final body weight, BWC=Body weight change, ADG=average daily gain, FCE=Feed conversion efficiency, PCE=Protein conversion efficiency, SEM=Standard error of the mean, SL=significance level, ns=non-significant.

3.4. Body weight gain

The mean values of initial and final body weight (BW), daily BW gain, and feed conversion efficiency (FCE) of the experimental animals are indicated in Table 4. The result indicated that the effect of the replacement was significant on average daily and final BW gain, final BW, FCE, and protein conversion efficiency (PCE) of experimental animals ($P > 0.05$).

3.5. Partial budget analysis

The partial budget analysis of Bonga sheep fed on PG hay and replaced different proportions of MFL with concentrates mix is presented in Table 5. The cost-benefit analysis of the replacement value of MFL with CM in this study is presented in Table 5. Accordingly, the lowest total variable cost recorded in T1, T2, T3, T4, T5 and T6 was 73.4, 134.35, 195.98, 258.03, 317.0, and 379.6 ETB/head, respectively. T6 has the highest net return recorded compared to other treatments, which was 310.4ETB/head and the second higher net return obtained from animals in T5, 222.99 ETB/head, followed by T4, T3, which was 131.9, 64.0 ETB/head respectively. A higher total return (310.4ETB/head) was obtained from the sheep-supplemented 201.9 g NSC following the sheep-supplemented 83g MFL+151.4 g NSC with a total return (of 222.99 ETB/head). As the partial budget analysis indicated, groups supplemented 201.9 g NSC and 83g MFL+151.4 g NSC returned a higher net income than the other groups.

Table 4. Partial budget analysis of Bonga sheep fed PG hay and supplemented with MFLL to replace NSC—cost-benefit.

Parameters	Treatment					
	T1	T2	T3	T4	T5	T6
Number of animals	7	7	7	7	7	7
Purchase price of lambs/head	610	610	610	610	610	610
Hay consumed per (kg /lamb)	35.6	35.4	35.9	36.6	35.3	36.4
Concentrate consumed per (kg/lamb)	40.1	40.1	44.9	49.4	54.03	58.5
MFL meal consumed per (kg/lamb)	0	29.8	22.41	14.9	7.47	0
Cost of hay (ETB/kg)	53.4	53.1	53.8	54.9	52.95	54.6
Cost of concentrate mix (ETB/kg)	401	401	449.5	494.9	540.3	585.8
Labor cost (ETB)	20	25	25	25	25	25
Cost of *Momordica foetida* leaf meal (ETB)	0	37.2	28.012	18.6	9.3	0
Total variable cost (TVC)	474.4	516.3	556.36	593.4	627.5	665.4
The selling price of lamb's ETB/head	690	780	870	1000	1150	1300
Total Return (TR)	215.6	263.6	313.6	406.5	522.4	634.6
Change in total return (TR)	0	48.0	98.03	190.9	306.8	419
Change in total variable cost (TVC)	0	41.9	81.9	119.0	153.1	191
Change in net return (NR)	0	6.1	16.075	71.95	153.625	228

Marginal rate of return (MRR)	0	0.14	0.19	0.60	1.00	1.192

ETB – Ethiopian birr, kg – kilogram, Δ – change in, TVC – total variable cost, NI-net income, MRR-marginal rate of return.

4. Discussion

The CP content of MFL in the current study is higher than the study [8] which supplemented dwarf West African goats with *Tephrosia canadida* and *Girilicida sepeium* browses species which contain (19.78 %) and (19.25 %) *Girilicida sepeium* and *Tephrosia*. Crude Protein content in this study was higher than [9], who reported CP for *Vernnonia amygdalin* (22.5%) and Mulbery (18.5). Furthermore, the CP content observed in the current study was consistent with the nutritive value of tropical forage plant *Moringa oleifera* (32.4 %) and *Acacia mangium* (17.7 %) fed to pigs reported by Kambashi [10].

In this study, the substitution positively affected the total DM intake of the experimental sheep. Higher intake was observed when more CP was present in the substituted diets. An animal with a daily body weight gain (of 150g/d) may be given daily intakes of (560g/d), (76g/d), and (6.4 MJ/kgDM) for DM, CP, and ME, respectively [11]. The increase in total DMI and nutrient intake because of the substitution is a common finding in various studies. The feed intake of sheep fed Vetch (*Lathyrus sativus*) haulm was increased by substituting wheat bran, *Acacia albida* leaf meal, or mixtures of these ingredients [12]. The current study's total dry matter intake was higher than previous studies (839-886 g/d) [13]. Instead, the current dry matter intake was lower than [14] total dry matter intake of (1330.7g-1400.9 g) but comparable to Desta's [15] total dry matter intake of (416.25g-919.96 g/kg DM /d). Variations in different results, including this finding, could be attributed to animal breed, forage type, microclimate, and feed preparation. In this study, CP intake was lower in the control group (39.42 g/kg DM) than in the supplemented groups (105.01-134.64 g/kg DM/d). This is consistent with the findings of Desta [15] and Tesfaye [16], who replaced mulberry leaf with varying levels of concentrate mix. In this study, however, fiber (NDFI) intake was variable and significantly (P<0.05) different between treatments. Thus, according to Van Soest and Robertson [17], it is a cell wall component of feed recovered in faeces.

The DM digestibility in this study was lower than the results of previous studies [18 & 19]. According to Zewdu's [20] DMD model, less than 65% was due to the model proposed for developing countries, where dry matter digestibility is typically low due to relatively low climatic conditions. According to the report of Rathod [21], biologically active chemicals in *M.foetida* are glycosides, saponins, alkaloids, fixed oils, triterpenes, proteins, and steroids that may have a reduced apparent digestibility.

In the current experiment, the digestibility of CP was significantly (P< 0.05) different among the treatment group. But the current result of CP digestibility was lower (63-87%) than Awoke [22], who supplemented Washera sheep with *Ficus sycomorus* Leaf, fruit, and their mixtures; Gezahegn [23] (73.0-81.0 %); and (76.0 %) [24]. While the current study's crude protein digestibility was comparable (62.0-79.0 %) [25], and the result was higher (56.8-60.9 %) [26]. The difference in digestibility between treatment groups could be due to the different feed compositions. Furthermore, according to McDonald [27], the digestibility of the feed is influenced by the composition of other feed consumed with it, and the associated effect can result in a higher or lower digestibility rate.

The difference in body weight change and average daily gain observed in this study could be attributed to differences in daily DM and CP intake and the digestibility of the respective treatment diets [28]. Feed conversion efficiency (FCE) significantly(P>0.001) between the dietary treatments.

Urge [29] reported 24.5 g/day body weight loss in *Adilo* sheep fed only grass hay and 13.2-36.1 g/d body weight gain in sheep supplemented with haricot bean screenings and sweet potato tubers. Similarly, the higher total DM and CP intake and better digestibility of the treatment diets may explain the increased weight gain and average daily gain in supplemented groups compared to the control group. The current study confirms with Mengistu [30] that MF leaves did not affect the final body weight of lambs. A significant difference (P>0.05) in weight gain between treatments. Furthermore, sheep supplemented with a higher level of NSC had greater (P>0.05) average daily gain 171.0 g/d, 152.0 g/d, and 124.1 g/d) for T6, T5, and T4, respectively. The difference in body weight

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change and average daily gain observed in this study could be attributed to differences in daily DM and CP intake and the digestibility of the respective treatment diets [31]. Feed conversion efficiency (FCE) significantly(P>0.001) between the dietary treatments.

The economic analysis indicated that total return (selling price of sheep) was higher for sheep fed on T6 and T5 diets due to higher final body weight resulting in 32.5 kg and 30.5 kg for T6 and T5. But T1 had a low rate of total return due to its low body weight(20.6kg). Among treatments, T5 has the optimum total return of 540ETB/head, which had a proportion of 25:75% NSC to MFL diet and had an optimum body weight of 33.8kg, followed by T4, which has 390ETB/head total return.T4 has an excellent daily weight gain 141.4g/day, changes in net return (67.95ETB/head) and 1.09 marginal rate of return .T5 has an excellent daily body weight gain 188g/day), 91.0 changes in net return and optimum marginal rate of return (1.5)compared to other treatments. T3 had 64.0 ETB net returns, 28.3 changes in net return, and 0.46 marginal rate of return, followed by T2 with 35.65 net return, 29.0 changes in net return, and 0.4 marginal rates of return were the lowest in economic feasibility. The changes in net return and marginal rate return indicated that per 1ETB increment investment to purchase concentrate (NSC) to attain required body weight by replacement with MFL meal could return 0.47, 0.46, 1.09, 1.5 and 1.3, respectively. Moreover, the MRR indicated that an additional unit of 1ETB per sheep cost increment resulted in 1ETB an additional 0.47, 0.46, 1.09, 1.5 and 1.3 benefits from T2, T3, T4, T5 and T6, respectively.

5. Conclusions

The feed mixture of T3 25 % MFL +75% NSC (83g MFL+151.4 g NSC) levels replace the NSC as a protein source in the diet, improving feed intake and body weight gain. Based on partial budget analysis, replacing MFL instead of NSC displayed a reduction in feed cost and an increase in net return. Therefore, replacing NSC with MFL at 25% is a viable option as an alternative protein source for Bonga sheep's production and productivity. However, further investigation is needed on the agronomic trait evaluation and anti-nutritional factors.

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Data Availability Statement: The data presented in this study are available upon reasonable request from the corresponding author.

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Conflicts of Interest: The authors declare no conflict of interest.

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