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Effect of partial substitution of Noug (*Guizotia abyssinica*) seed cake with graded levels of sainfoin (*Onobrychis viciifolia*) hay on growth performance and carcass characteristics of yearling rams

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A feeding trial was conducted using sainfoin hay at 0, 10, 20 and 30% on a dry matter basis of inclusion to yearling rams placed on, T1, T2, T3 and T4, respectively, to substitute Noug seed cake in concentrate (wheat bran + Noug seed cake + common salt + wheat straw as a basal diet). Yearling 24 rums were selected on the basis of age and weight similarity and randomly assigned to the four treatments in RCBD with six replicates. At the end of the 90-day feeding trial, three sheep per treatment were randomly assigned either for the digestibility trial and/or carcass characteristics evaluation. Crude protein (CP) digestibility, daily weight gain, and feed conversion efficiency recorded the highest in T4 and T2. Lower dressing percentage with higher ether extract was recorded in T1. The rib eye muscle CP recorded the highest in T2 and T3. Lower water-to-protein ratio and higher caloric value were higher in T2 and T3 and T2, respectively. The marginal rate of return was the highest in T4, followed by T2. Therefore, the inclusion of a graded-level of sainfoin hay as a substitute for the expensive Noug seed protein in a tropical poor roughage basal diet seems to be appealing under the current Ethiopian condition.

Key words: Feed conversion efficiency, Noug seed cake, sainfoin hay, nutrient digestibility, nutrient retention, water to protein ratio, weight gain.

INTRODUCTION

Ethiopia has the largest livestock population in Africa, comprising about 70.29 million cattle, 40 million sheep, 51 million goats, 9.9 million donkeys, 2.1 million horses, 0.35 million mules, 8 million camels, 49 million chickens, and 6.9 million beehives (CSA, 2020). The sub-sector contributes 60 to 70% of the livelihoods of the Ethiopian

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Table 1. Allocation of treatment feeds to the experimental animals

Treatments	Replication/Treatment
Basal ration, control treatment (T1)	6
Basal ration + 10% sainfoin hay as substitute for NSC protein (T2)	6
Basal ration + 20% Sainfoin hay as substitute for NSC protein (T3)	6
Basal ration + 30 % Sainfoin hay as substitute for NSC protein (T4)	6

T1, Control feed containing wheat straw plus concentrate mixture; NSC, Noug seed cake.

population including family income generation, job creating opportunities, ensuring food security, service provision, asset building and social, cultural and environmental values sustaining (FAO, 2018). The livestock sub-sector is accountable for 17% the national and 39% for agricultural GDP (Shapiro et al., 2017).

Among the Ethiopian livestock resource, sheep are particularly important in generating income and providing of animal proteins at the household level. In Ethiopia, sheep are predominantly slaughtered during festive and religious occasions (Bella and Haile, 2009). However, the contribution of the Ethiopian sheep resource to human nutrition, national economy and export earnings are disproportionally low attributed to inadequate nutrition. The existing natural pasture and the conventional proteins and energy supplements are inadequate to support reasonable animal performance. This situation warrants the searching, evaluation and inclusion of perennial herbaceous legumes like sainfoin in ruminant animal feeding system.

Sainfoin is a highly palatable and nutritious forage legume used for hay and pasture production (Delgado et al., 2008). Nutritionally, partial replacement of grass silage by sainfoin silage, resulted in a 5 to 10% increase in dietary intake and milk production and in reduction of 12% of methane emission per kilogram of milk production (Martin et al., 2010). Moreover, feeding sainfoin silage enhanced a marked increase in the linoleic acid and total omega-3-fatty acid content in lamb meat (Girard et al., 2016). The local availability and utilization practice in the study area and effect of varying levels of this plant on performance of animals has not been studied in Ethiopia. Therefore, the objective of this research was to evaluate the effect of substitution of Noug seed cake with graded sainfoin hay on growth and carcass characteristics of yearling lambs.

MATERIALS AND METHODS

Description of the study area

This study was conducted at “Gummer Sheep Breed Improvement Station” found near Arekit town of Gummer Woreda (district). Gummer Woreda is located at 220 km South of Addis Ababa, at latitude of 7°4’59.99’’N and longitude of 38°04’60.00E. The mean annual rain fall of Gummer Woreda ranges between 1200 and 1400 mm. The Woreda has two rainy seasons between June-September and February-April. The mean temperature of Gummer ranges between 16 and 21°C and 18 and 26°C (Getu et al., 2019).

Laboratory chemical analysis

Wheat straw, wheat bran, Noug seed cake and common salt were used to formulate the concentrate of this study. The sub-samples of all the experimental feed ingredients, the treatments diet offered, refusals, feces and meat were processed and subjected to laboratory chemical analysis. The procedure of AOAC (2005) was applied for determination of dry matter (DM), total ash, ether extract (EE) and crude protein (CP). The N content was determined by the Kjeldahl method and the CP content was calculated as N×6.25. Neutral detergent fiber (NDF) was determined according to Van Soest et al. (1991) and acid detergent fiber (ADF) and acid detergent lignin (ADL) were determined according to Van Soest and Robertson (1985). Calcium and phosphorous were determined according to AOAC (2005), using Spectrophotometer. Metabolizable energy content was estimated using the following formula (MAFF, 1975):

$$ME\ (MJ/kg\ DM) = 0.15 \times IVDOMD\ (g/kg)$$

Preparation of the experimental treatments

Wheat straw obtained from Soddo Woreda was used as one of basal diet ingredient. Sainfoin was harvested at 75% flowering stage, chopped to a length of about 4 to 6 cm and sun dried. Noug seed cake, wheat bran and common salt were purchased from local market. Concentrate mixture containing Noug seed cake, wheat bran and common salt was prepared based on the results of the laboratory analytical data to contain 2.55 Mcal of energy/kg of DM of metabolizable energy and 16% of crude protein. Four iso-caloric and iso-nitrogenous treatment rations (Table 1) were formulated, based on the results of the laboratory feed analytical data to meet the nutrient requirement of the experimental lambs (Kearl, 1982). Sainfoin hay was included at 0, 10, 20 and 30% in total DM as substitute for Noug seed cake calculated protein in treatments 1, 2, 3 and 4, respectively.

Management of the experimental animals

Twenty-four yearling rams were obtained from Gummer Sheep Improvement Station in Gummer Woreda. The sheep were sprayed against external parasites, dewormed and acclimatized to their environment and feed for 10 days. At the end of the acclimatization period, the animals were individually weighed and divided into four groups each with six sheep. Each group was further subdivided into six and each sheep was housed in individual pen equipped with feeding and watering troughs. Then, the four treatments shown in Table 1 were assigned to the experimental sheep in Completely

Randomized Block Design for a period of 90 days feeding trial. The treatment feeds were provided twice per day (08:00 and 14:00 h) in separate troughs. The refusals were separately collected in separate bags and weighted. Daily intake was calculated as a difference between offers and refusals. Feed offered was sampled fortnightly but refusals were sampled daily and bulked for chemical analysis. Clean drinking water was made available all the times.

Data collected

Nutrient composition, body weight change and feed conversion ratio

The nutrient composition of the experimental feed ingredient was determined by laboratory chemical analysis. Data on weight changes of each experimental sheep was collected every two weeks (fortnightly) up to the end of experimental periods. Daily weight gain was calculated as the difference between the final and initial body weight divided by the number of feeding days. Feed conversion efficiency was calculated using the following formula suggested by Köksal et al. (2000) and Brown et al. (2001).

$$\text{Feed conversion efficiency} = \left[\frac{\text{Average daily live weight gain (g)}}{\text{average daily feed intake (g)}}\right] \times 100\%$$

Digestibility determination

At the end of the feeding trial, two sheep were randomly selected from each treatment group and transferred in to individual metabolic cages for separate collection of feces and urine. The animals were allowed to adapt to feces collection bags for 5 days followed by 7 days of collection period. The sheep were maintained on similar treatment diets of the initial feeding trial. Total daily feces was weighed, thoroughly mixed, and 10% aliquot sample was saved. The feces samples were stored at -20 °C in district animal health clinic until the end of collection period. The sampled feces, offered feed and refusals were oven dried at 60 °C for 72 hours; milled to pass through 1 mm screen, and stored in polythene bags until analysis. Digestibility was calculated using the following formula,

$$\text{Apparent nutrient digestibility} = \left[\frac{\text{Nutrient in feed} - \text{Nutrient in feces}}{\text{Nutrient in feed}}\right] \times 100\%$$

Measurements of carcass characteristic

At the end of the feeding trial, randomly selected 3 sheep per treatment were fastened, weighted and slaughtered. Slaughtering was carried out by severing the jugular vein and the blood was collected and weighed. The skin, legs, head (with horn and ear), organs, gut fill and empty gut were weighed separately. Hot carcass was weighed. Dressing percentage was calculated as proportion of hot carcass weight to empty body weight and to slaughtering body weight. The rib eye muscle (*Longismus dorsi*) area was measured at the 12 and 13th rib sites perpendicular to the back bone to measure the cross-section of the rib eye area (REA). Carcasses were cut into parts as commercial methods used in Ethiopia. The cut samples were sealed in a plastic bag and frozen at -20°C until meat quality assessment. Proximate analysis was carried out at Hawassa College of Agriculture Nutrition Laboratory whereas mineral content (Ca and P) analysis were carried out at Holeta Agricultural Research Center in Soil Laboratory section.

Water-holding capacity (WHC, %) was measured using the procedure described by Grau and Hamm (1953). Five grams of fresh sample of raw meat from each treatment was cut. The cut samples were again cut into small pieces, covered with two filter papers and two thin plates of glass material and pressed with a weight of 2.5 kg pressing metal for 5 min. The samples were removed from the filter paper and their weight was calculated in relation to the initial weight. Moisture-to-protein (W/P) ratio was calculated as an indication of physiological maturity (Brzostowski et al., 2008). Caloric value (meat energy), based on protein and lipid contents was calculated using the following specific calorie factors as driven by FAO (2003).

$$\text{ME (Kcal)} = \text{g protein} \times 4.27 + \text{g fat} \times 9.02$$

Partial budget analysis

The market price of the experimental sheep was obtained from village farmers' and traders. The variable cost for each work was recorded. Partial budget analysis was calculated according to the procedure suggested by Upton (1979) for measuring profit margin for each treatment. Net income (NI) was determined as the amount of money left when total variable costs (TVC) were subtracted from total return (TR). Change in net income (ΔNI) was calculated by subtracting change in total variable cost (ΔTVR) from change in total return (ΔTR). Marginal rate of return (MRR) was taken for the advantage to measure the increase in net income (ΔNI) associated with each additional unit of expenditure (ΔTVC) and it was calculated as:

$$\text{MRR} = ((\Delta NI / \Delta TVC) \times 100)$$

Statistical analysis

Numerical data were managed and organized by MS-Excel and analyzed using General Linear Model (GLM) procedure by using SAS (2011), version 9.3. Means were separated using Duncan's multiple range tests and variance differences were declared as significant at $p<0.05$. The model for the treatment and block effect was calculated as:

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

where Yij = the responsible variable; μ = the overall mean; T_i = the i^{th} treatment effect; βj = the j^{th} block effect; and eij = the random error.

RESULTS

Chemical composition of the experimental feeds

The chemical compositions of the experimental feed ingredients are presented in Table 2. Compared to the other experimental feed ingredients, significantly lower metabolizable energy, crude protein, ether extract, calcium and phosphorus contents were recorded from wheat straw. On the contrary, significantly ($p<0.05$) higher NDF and ADF contents were recorded from wheat straw.

Feed and nutrient intake of the experimental sheep

The mean daily feed intake of the experimental animals is

Table 2. Chemical composition of the experimental feed ingredient sampled before mixture preparation.

Ingredients (%)	Wheat straw	Wheat bran	Noug cake	Sainfoin hay	CV%	LSD	LS
DM	92.33^{a}	92.70^{a}	92.30^{a}	90.30^{b}	2.31	1.27	**
OM	90.10^{ab}	95.04^{a}	89.70^{ab}	87.28^{b}	2.31	6.40	NS
Total ash	9.94	4.46	10.30	11.80	2.31	6.92	NS
CP	4.40^{c}	16.21^{b}	31.71^{a}	17.00^{b}	2.31	1.11	***
EE	0.77^{c}	3.61^{a}	0.82^{c}	2.10^{b}	2.31	0.59	***
NDF	73.60^{a}	44.40^{c}	39.20^{d}	52.00^{b}	2.31	2.88	***
ADF	44.20^{a}	14.50^{d}	29.83^{c}	35.00^{b}	2.31	4.18	***
ADL	8.70^{ab}	2.80^{b}	8.40^{ab}	17.70^{a}	2.31	11.44	NS
ME	1.74^{c}	3.24^{a}	2.14^{b}	2.39^{b}	2.31	0.39	**
Ca	0.26^{b}	0.76^{a}	0.73^{a}	0.80^{a}	2.03	0.09	***
P	0.23^{c}	0.86^{b}	1.12^{a}	0.26^{c}	2.31	0.16	***

Means in the same row without similar superscript letters are significantly different at $p< 0.05$. CV, Critical value; LSD, least significant difference; LS, level of significance; ****, p<0.0001; **, p<0.001;* NS, not significant.

Table 3. Mean feed ingredients' nutrient intake of the experimental sheep during the experimental sessions.

Feed item (g/day/h)	T1	T2	T3	T4	CV%	LSD	LS
Total feed							
DM intake	695.65^{d}	759.26^{b}	771.25^{a}	735.30^{c}	2.31	3.68	***
CP intake	120.43^{b}	127.76^{a}	129.04^{a}	123.64^{b}	2.31	3.24	***
ME intake	1.83^{b}	1.96^{a}	2.01^{a}	1.92^{a}	2.31	0.09	***
W. Straw							
DM intake	155.64^{ab}	168.98^{a}	137.86^{b}	97.33^{c}	2.09	13.34	***
CP intake	6.83^{b}	7.43^{a}	6.06^{b}	4.28^{c}	2.09	0.60	***
ME intake	0.27^{ab}	0.293^{a}	0.24^{b}	0.17^{c}	2.09	0.02	***
Concentrate							
DM intake	539.71^{a}	510.32^{a}	468.98^{ab}	402.29^{b}	2.09	72.63	**
CP intake	113.60^{a}	107.18^{ab}	95.93^{b}	80.59^{c}	2.09	15.02	***
ME intake	1.56^{a}	1.48^{a}	1.38^{ab}	1.19^{b}	2.09	0.21	***
Sainfoin	539.71^{a}	510.32^{a}	468.98^{ab}	402.29^{b}	2.09	72.63	**
DM intake	0	79.96^{c}	164.41^{b}	235.68^{a}	2.13	28.81	***
CP intake	0	13.15^{c}	27.05^{b}	38.77^{a}	2.13	4.74	***
ME intake	0	0.19^{c}	0.39^{b}	0.56^{a}	2.13	0.07	***

Means in same row in each feed ingredient without similar letter are significantly different at $p<0.05$. T1, Control feed (wheat straw + concentrate mixture containing + 0% sainfoin hay); T2, wheat straw + concentrate mixture containing a 10% sainfoin hay that replace equivalent NSC; T3= wheat straw + concentrate mixture containing a 20% sainfoin hay that replace equivalent NSC; T4, wheat straw + concentrate mixture containing a 30% sainfoin hay that replace equivalent NSC; CV, critical value; LSD, least significant difference; LS, level of significance; ****, p<0.0001; **, p<0.001;* NS, not significant.

presented in Table 3. Relatively lower mean total daily DM, CP and ME intake was recorded from the groups fed on T1 (control treatment). The mean daily total DM consumption of the groups fed on T1 (695.65 g/head/d) was significantly ($p<0.05$) lower than that of the others. However, there was no significant difference between the groups assigned to T2 (10% sainfoin) and T3 (20% sainfoin) as substitute for Noug seed cake protein on one side and between T1 (0% sainfoin) and T4 (30% sainfoin) as substitute for Noug seed cake on the other side in mean total daily CP consumption, respectively. This results indicate that inclusion of 10 to 20% sainfoin as

Table 4. The mean chemical composition of the refusal feed during the experimental session.

Ingredients (%)	Treatments						
	T1	**T2**	**T3**	**T4**	**CV%**	**LSD**	**LS**
DM	94.00	93.26	93.69	93.53	2.31	1.08	NS
OM	91.52	91.54	92.08	92.47	2.31	1.16	NS
Total ash	8.48[a]	8.46[a]	7.92[b]	7.53[c]	2.31	0.25	***
CP	6.74[a]	5.88[b]	5.21[c]	2.18[d]	2.31	0.30	***
EE	0.71	0.73	0.72	0.71	2.31	0.01	NS
NDF	52.2[a]	51.2[ab]	49.90[b]	48.10[c]	2.31	1.41	*
ADF	26.5	26.97	27.20	26.73	2.31	1.74	NS
ADL	5.60[a]	5.52[ab]	5.41[ab]	5.14[b]	2.31	0.44	NS
ME (kcal/kg DM)	0.60	0.62	0.64	0.67	2.31	0.10	NS
Ca	0.68[a]	0.63[ab]	0.57[b]	0.56[b]	2.31	0.10	NS
P	1.78	1.54	1.20	1.10	2.31	0.96	NS

Means in same row without similar letter are significantly different at $p<0.05$. T1, Control feed (wheat straw + concentrate mixture containing + 0% Sainfoin hay); T2, wheat straw + concentrate mixture containing a 10% sainfoin hay that replace equivalent NSC; T3, wheat straw + concentrate mixture containing a 20% sainfoin hay that replace equivalent NSC; T4, wheat straw + concentrate mixture containing a 30% sainfoin hay that replace equivalent NSC; CV, critical value; LSD, least significant difference; LS, level of significance; ***, $p<0.0001$; *, $p<0.05$; NS, not significant.

substitute for NSC protein significantly improved the mean daily total DM, CP and ME intake of the experimental lambs. Inclusion of 10 to 20% sainfoin hay into the basal ration as substitute for NSC resulted in a 9-10, 6-7, and 7-9% increase in mean daily total DM, CP, and ME intake of the experimental lambs, respectively. However, the inclusion of 30% of sainfoin in basal ration as substitute for NSC protein (T4) tended a non-significant increase in feed and nutrient consumption over that of the groups fed on control treatment.

Mean daily DM, CP, and ME intake from wheat straw showed significant improvement for the groups fed on T2 (10% Sainfoin) compared to the others. Increment in the amount of inclusion of sainfoin in the basal ration (20-30% sainfoin) resulted in proportional decrease in DM, CP, and ME of wheat straw. Significantly higher DM, CP, and ME intake from concentrate was recorded from the groups fed on T1 (0% sainfoin).

As indicated in Table 4, significantly ($p<0.05$) higher CP and NDF contents were recorded from the ort (refusal) of the groups fed on T1. The relatively higher CP content of the orts (refusal) of the groups fed on T1 could be attributed to higher intake limiting factors (NDF and ADL) in the diet. According to Table 4, with the exception of total ash and CP content, there was no significant ($p>0.05$) difference in nutrient composition of the feed offered in chemical composition. Variability in total CP intake of the treatment groups could be attributed to the feeding habits of sheep which select the most nutritious parts of the straw.

Relatively lower mean daily intake of DM, CP, and ME from concentrate was recorded from the groups fed on T1, while relatively lower mean daily DM, CP and ME intake from concentrate was recorded from the groups fed on T4 (30% sainfoin). On the contrary, DM, CP and ME intake from sainfoin was relatively higher for the groups placed on T3 (20% sainfoin) indicating that inclusion of sainfoin hay beyond 20% as substitute for NSC protein could depress feed intake.

Apparent digestibility of the experimental feed

The results of the apparent digestibility of the treatment diets are presented in Table 5. There were significant variations ($p<0.05$) between the treatment diets in mean digestibility of nutrients with the exception of CP ($p<0.05$). Significantly higher ($p<0.05$) DM digestibility was recorded from the groups fed on T4 followed by that of the groups fed on T2. On the other side, significantly lower ($p<0.05$) mean DM digestibility was recorded from the groups fed on T1. There was no significant difference ($p>0.05$) between all the treatment groups in mean CP digestibility.

The groups fed on T4 (30% sainfoin) and T1 (0% sainfoin) achieved significantly higher and lower ($p<0.05$) mean NDF digestibility, respectively. Significantly higher ($p<0.05$) mean ADF and ADL digestibility was recorded from the groups fed on T4 (30% sainfoin).

Lambs assigned to T4 (30% sainfoin), showed significantly higher mean digestibility of ADF (43.32%), while the groups assigned to T1 showed lower mean digestibility (36.61%) of ADF.

The ADL was better digested by groups of lambs fed on

Table 5. Apparent digestibility of the experimental feed collected and sampled during the experimental session.

Feed ingredients	T1	T2	T3	T4	CV%	LSD	LS
DM digestibility (%)	86.74[d]	91.55[b]	88.81[c]	97.13[a]	2.31	1.54	***
CP digestibility (%DM)	92.28	93.2 0	94.94	98.40	2.31	2.31	ns
NDF digestibility (%DM)	52.31[c]	54.29[c]	61.99[b]	70.50[a]	2.31	2.97	***
ADF digestibility (%DM)	36.61[c]	40.12[b]	40.48[b]	43.32[a]	2.31	2.28	**
ADL digestibility(%DM)	22.81[c]	28.90[a]	25.25[b]	28.94[a]	2.31	2.26	**

Means in same row without similar letter are significantly different at p<0.05. T1, Control feed (wheat straw + concentrate mixture containing + 0% Sainfoin hay); T2, wheat straw + concentrate mixture containing a 10% sainfoin hay that replace equivalent NSC; T3, wheat straw + concentrate mixture containing a 20% sainfoin hay that replace equivalent NSC; T4, wheat straw + concentrate mixture containing a 30% sainfoin hay that replace equivalent NSC; CV, critical value; LSD, least significant difference; LS, level of significance; ****, p<0.0001; ** , p<0.001;* ns, not significant.

Table 6. Mean growth performance and feed conversion efficiency of experimental sheep fed experimental diets for nighty days.

Parameter	Treatments						
	T1	T2	T3	T4	CV%	LSD	LS
Growth Performance							
Initial body weight (kg/head)	17.83	18.17	18.58	18.33	2.09	2.97	NS
Final body weight (kg/head)	21.00[b]	24.30[a]	22.70[ab]	23.17[ab]	2.09	3.18	**
Total weight gain (kg/head)	3.17[c]	7.58[a]	4.08[bc]	5.62[b]	2.09	1.79	***
Daily gain (g/head)	38.00[c]	90.17[a]	48.83[bc]	67.00[b]	2.09	21.31	***
Feed Conversion							
Total feed intake (kg/head)	68.07	74.62	76	72.48	2.09	11.15	NS
Daily feed intake (g/head)	756.00	829.00	844.00	805.00	2.09	123.93	NS
Consumed feed (g)/gain (g)	21.47[a]	9.5[c]	18.63[ab]	12.90[b]	2.09	14.55	**
FCE (%) (daily gain (g)/daily consumed feed (g) ×100%)	5.15[c]	11.05[a]	5.60[bc]	8.48[ab]	2.086	3.01	**

Means in same row in each parameter without similar letter are significantly different at p<0.05. T1, Control feed (wheat straw + concentrate mixture containing + 0% Sainfoin hay); T2, wheat straw + concentrate mixture containing a 10% sainfoin hay that replace equivalent NSC; T3, wheat straw + concentrate mixture containing a 20% sainfoin hay that replace equivalent NSC; T4, Wheat straw + concentrate mixture containing a 30% sainfoin hay that replace equivalent NSC; CV, critical value; LSD, least significant difference; LS, level of significance; ****, p<0.0001; ** , p<0.001;* NS, not significant.

T2 (10% sainfoin) and T4 (30% sainfoin).

Growth performance and feed conversion efficiency

The results of growth performance and feed conversion efficiency of the experimental sheep fed on the treatment diets are presented in Table 6. Mean total and daily weight gain attained by the groups fed on T2 (10% sainfoin) was significantly higher than the others followed by that of the groups fed on T4 (30% sainfoin). On the contrary, mean total and daily weight gain attained by the groups fed on T1 (0% Sainfoin) was significantly (p<0.05) lower than that of the others. Feed consumed per unit body weight gain (21.47 g) by the groups fed on T1 (0%sainfoin) was relatively higher followed by that of the groups placed on T3 (20% sainfoin). Feed conversion efficiency was relatively higher (p<0.05) (11.05%) for the groups fed on T2 (10% sainfoin) followed by that of the groups fed on T4 (8.48), indicating that these two treatment diets were efficient in conversion compared to the others. Inclusion of 10 and 30% sainfoin hay decreased feed consumption per unit body weight gain and found to be more efficient in utilization of nutrients compared to the others.

Carcass and non-carcass characteristics of experimental sheep

Hot carcass weight and dressing percentages

The results of hot carcass weight and depressing percentage of the experimental sheep are presented in Table 7. The hot carcass weight was similar across the

Table 7. Carcass characteristics of experimental sheep fed experimental diets for nighty days.

Measured carcass parts	Treatment						
	T1	T2	T3	T4	CV%	LSD	SL
Hot carcass weight (kg/head)	8.28	11.83	9.83	10.41	2.31	4.05	NS
Dressing percentage (%SBW)	41.9^{b}	49.19^{a}	44.03^{ab}	44.54^{ab}	2.31	6.57	NS
Dressing percentage (%EBW)	50.18^{b}	65.32^{a}	56.09^{ab}	55.48^{b}	2.31	9.33	*
Rib eye area (cm^2)	4.05	4.47	4.23	4.36	2.31	0.87	NS

Means in same row in each parameter without similar letter are significantly different at *p*<0.05. T1, control feed(wheat straw + concentrate mixture containing + 0% Sainfoin hay); T2, wheat straw + concentrate mixture containing a 10% sainfoin hay that replace equivalent NSC; T3, wheat straw + concentrate mixture containing a 20% sainfoin hay that replace equivalent NSC; T4, wheat straw + concentrate mixture containing a 30% sainfoin hay that replace equivalent NSC; CV, critical value; LSD, least significant difference; LS, level of significance; **, p<0.05;* NS, not significant.

Table 8. Edible and non-edible offal components of experimental sheep fed experimental diets for nighty days.

Measured carcass parts	Treatment						
Edible offal	**T1**	**T2**	**T3**	**T4**	**CV%**	**LSD**	**SL**
Tongue(kg)	0.12	0.10	0.31	0.12	2.31	0.35	NS
Liver(kg)	0.43	0.47	0.52	0.43	2.31	0.24	NS
Kidney(kg)	0.12	0.16	0.08	0.10	2.31	0.13	NS
Heart(kg)	0.10	0.19	0.11	0.12	2.31	0.10	NS
Testicles(kg)	0.33	0.37	0.36	0.37	2.31	0.17	NS
Empty gut(kg)	1.43	1.72	1.40	1.48	2.31	0.66	NS
Blood(kg)	1.43	1.63	1.00	1.50	2.31	0.64	NS
Edible offal(kg) sum	3.94	4.63	3.79	4.12	2.31	0.98	NS
Non-edible offal							
Head(kg)	1.57^{b}	2.30^{a}	1.72^{ab}	1.98^{b}	2.31	0.65	NS
Feet(kg)	0.52^{ab}	0.58^{a}	0.40^{bc}	0.38^{c}	2.31	0.13	*
Lung and trachea(kg)	0.35	0.35	0.34	0.38	2.31	0.13	NS
Spleen(g)	20.67^{b}	24.33^{ab}	23.20^{ab}	25.37^{a}	2.31	3.85	NS
Skin(kg)	3.00	2.50	4.02	4.13	2.31	1.89	NS
Gut content(kg)	1.80	2.08	2.02	1.87	2.31	0.57	NS
Non-edible offal sum(kg)	7.44	8.04	8.73	9.00	2.31	2.06	NS

Means in same row in each parameter without similar letter are significantly different at *p*<0.05. T1, Control feed (wheat straw + concentrate mixture containing + 0% sainfoin hay); T2, wheat straw + concentrate mixture containing a 10% sainfoin hay that replace equivalent NSC; T3, wheat straw + concentrate mixture containing a 20% sainfoin hay that replace equivalent NSC; T4, wheat straw + concentrate mixture containing a 30% sainfoin hay that replace equivalent NSC; CV, critical value; LSD, least significant difference; LS, level of significance; **, p<0.05;* NS, not significant.

treatments. Similarly, dressing percentage to slaughtering body weight ratio was found similar within the treatments. In contrast to slaughtering body ratio, dressing percentage to empty body weight ratio was higher for the groups fed on T2 compared with that of the groups fed on T1. There was no significant (*p*>0.05) difference between the other treatment groups in carcass characteristics (*p*>0.05).

Edible and non-edible offal components

The results of edible and non-edible offal components are presented in Table 8. With the exception of feet weight, all the other edible and non-edible offal weights of among the treatment groups were comparable (*p*>0.05)

The chemical composition of the rib-eye muscle

The result of the chemical composition of the rib-eye muscle of the experimental sheep is presented in Table 9. Rib-eye muscles of the groups fed on T4 contain significantly higher DM% followed by that of the groups placed on T1. On the other side, significantly lower DM% was obtained from the groups fed on T2. The groups of sheep placed on T3 and T4 contained lower and similar EE while the groups of sheep fed on T1 was significantly

Table 9. Chemical composition and characteristics of sampled Rib eye muscle (*Longismus dorsi*) of the experimental sheep that fed experimental diets for nighty days.

Parameter	Treatments						
	T1	T2	T3	T4	CV	LSD	LS
Dry matter (%)	93.18^{b}	92.93^{d}	93.00^{c}	93.27^{a}	2.31	0.02	***
Organic matter (%)	90.76^{a}	89.7^{c}	90.05^{bc}	90.40^{ab}	2.31	0.48	***
Ash (%)	2.42^{c}	3.23^{ab}	3.33^{a}	2.84^{bc}	2.31	0.48	***
Ether extract (%)	6.49^{a}	6.15^{b}	5.04^{c}	5.19^{c}	2.31	0.18	***
Crude protein (%)	19.80^{c}	21.90^{a}	22.22^{a}	21.25^{b}	2.31	0.60	***
Neutral detergent fibre (%)	69.41^{a}	67.76^{a}	68.53^{a}	64.64^{b}	2.31	2.51	**
Acid detergent fibre (%)	15.62^{a}	14.73^{a}	13.92^{a}	9.50^{b}	2.31	1.74	***
Acid detergent lignin (%)	1.51^{b}	0.83^{bc}	0.04^{c}	2.97^{a}	2.31	0.10	***
Calcium (%))	1.38^{b}	1.09^{c}	0.98^{d}	2.11^{a}	2.31	0.10	***
Phosphorus (%)	0.93^{a}	0.94^{b}	0.86^{b}	0.86^{a}	2.31	0.04	***
Caloric value (kcal/100g)	143.07^{b}	148.96^{a}	140.31^{bc}	137.54^{c}	2.31	3.01	***
Water holding capacity(% water)	66.53^{b}	67.10^{a}	68.30^{a}	68.90^{a}	2.31	2.10	***
Water/protein ratio	3.36^{a}	3.06^{b}	3.07^{b}	3.24^{a}	2.31	0.14	**

Means in same row in each parameter without similar letter are significantly different at $p<0.05$. T1, Control feed (wheat straw + concentrate mixture containing + 0% Sainfoin hay); T2, wheat straw + concentrate mixture containing a 10% sainfoin hay that replace equivalent NSC; T3, wheat straw + concentrate mixture containing a 20% sainfoin hay that replace equivalent NSC; T4, wheat straw + concentrate mixture containing a 30% sainfoin hay that replace equivalent NSC; CV, Critical value; LSD, least significant difference; LS, level of significance; ****, p<0.0001; **, p<0.001;* NS, not significant.

higher in EE than the others. The muscle of the groups fed on T2 and T3 contained significantly higher (p<0.05) CP content than those fed on T1 and T4. Comparatively, lower muscle deposition was recorded from the groups fed on T1. The fiber (NDF) content of muscle of sheep fed on T4 was lower than the others. The caloric value of muscles obtained from the groups fed on T3 and T4 were lower than the others. The muscles caloric value obtained from the groups fed on T2 is significantly higher (p<0.05) than the others. Water to protein ratio was lower in muscle obtained from the groups placed on T2 and T3.

Economic feasibility

The results of partial budget analysis are presented in Table 10. Significantly higher (p<0.05) gross income was recorded for the groups fed on T2 followed by that of the groups fed on T4. On the contrary, significantly lower gross income was recorded from the groups fed on T1. A unit change per treatment (MRR) was found to be higher for the groups fed on T4 followed by that of the groups fed on T2. The groups fed on T1 scored significantly (p<0.05) lower in MRR than the others. Feeding T4 was found to be 2.47, 1.02 and 1.43 times more profitable than feeding T1, T2 and T3, respectively and feeding T2 was found to be 2.42 and 1.4 times more profitable than feeding T1 and T3, respectively.

DISCUSSION

The results of chemical composition in the current study are not consistent with other similar findings. Compared with the present result, Derbie et al. (2019) reported higher NDF, ADF and ADL but lower CP content of wheat straw sampled from highland area. Gashaw and Defar (2016) noted lower CP, ADF and ADL contents with similar NDF with the present result for wheat straw sampled from two locations. On the other hand, Adugna (2008) indicated similar NDF and CP contents but lower ADL contents compared with the results of the present study. Variability could be attributed to differences in sample composition, variety, and laboratory facility.

Among the four experimental feed ingredients used, wheat straw seems to be poor in nutritive value, because it is low (4.40%) in CP content. Feed resource with CP contents of less than 7% impairs the rumen function resulting in poor digestion, low dry matter intake and poor animal performance (Topps, 1995). The higher NDF in wheat straw may limit ruminal fill and intake. The ADF content in wheat straw could also limit nutrient availability because it has a negative correlation with feed digestibility. Therefore, the result of this study suggested that, there is a need to supplement wheat straw with protein rich feed like Noug seed cake to improve the performance of experimental lambs (Arefaine and Melaku, 2017).

The DM and OM content of sainfoin hay was slightly lower than that of the others. Sainfoin hay contain about 11.8% of total ash, the value of which was higher than that of all the other experimental feed ingredients. The relatively higher total ash content of sainfoin seems to be partially attributed to its relatively higher content of calcium (0.80%). The mineral element considered to be

Table 10. Cost and benefit analyses of feeding trial for nighty days of experimental period calculated on the basis of the four treatments.

Parameter	Treatments						
	T1	T2	T3	T4	CV	LSD	LS
1. Land rent (Birr)	500.00	500.00	500.00	500.00	-	-	
2. Wage cost (Birr)	3150.00	3150.00	3150.00	3150.00	-	-	NS
3. Feed cost (Birr)	8317.00[a]	7842.00[a]	7102.00[b]	5911.00[c]	2.31	512..33	***
4. Sheep cost (BW ×160Birr)	17120.00[c]	17600.00[b]	18000.00[a]	17600.00[b]	2.31	304.25	**
5. Technical man cost (Birr)	2000.00	2000.00	2000.00	2000.00	-	-	NS
a. Sum of fixed costs (Birr)	31087.00[a]	31092.00[a]	30752.00[b]	29161.00[c]	2.31	139.24	***
b. Income tax (2%)	705.60[c]	816.48[a]	762.72[b]	778.52[b]	2.31	35.34	***
6. Medicine cost (Birr)	78.00	68.00	81.00	67.00	2.31	14.18	NS
7. Other costs (Birr)	120.00[b]	136.5.00[a]	141.00[a]	135.00[a]	2.31	11.84	**
c. Variable cost (Birr)(sum)	198.00[b]	204.50[b]	222.00[a]	202.00[b]	2.31	15.96	**
d. Gross income due	35280.00[d]	40824.00[a]	38136.00[c]	38926.00[b]	2.31	181.32	***
e. Gross revenue(d-a)(Birr)	4193.00[d]	9732.00[b]	7384.00[c]	9765.00[a]	2.31	27.85	***
f. Net income (NI=e-(b+c))	3289.40[d]	8711.02[b]	6843.28[c]	8784.48[a]	2.31	43.96	***
Δ NI	3406.10[c]	8506.52[a]	6621.28[b]	8582.48[a]	2.31	108.55	***
ΔTVC	198.00	204.50	222.00	202.00	-	-	
MRR	1720[d]	4160[b]	2983[c]	4249[a]	2.306	16.522	***
Sainfoin hay inclusion advantage over concentrate	-	2.42[a]	1.73[b]	2.47[a]	2.306	0.057	***

Means in row wise without similar letter are significantly different at $p<0.05$. Δ NI, Net income; ΔTVC, change in total variable cost; MRR, marginal rate of revenue; T1, control feed(wheat straw + concentrate mixture containing 0% Sainfoin hay; T2, wheat straw + concentrate mixture containing a 10% sainfoin hay that replace equivalent NSC; T3, wheat straw + concentrate mixture containing a 20% sainfoin hay that replace equivalent NSC; T4, wheat straw + concentrate mixture containing a 30% sainfoin hay that replace equivalent NSC; CV, critical value; LSD, least significant difference; LS, level of significance; ****, p<0.0001; **, p<0.001;* NS, non-significance.

deficient in cereal grains, indicating that sainfoin hay could have supplementary relationship with concentrate in terms of calcium and/or mineral nutrition. The phosphorus content of sainfoin hay is lower than that of wheat bran (0.86%) and Noug seed cake (1.12%). Phosphorus is considered as critically limiting mineral element in animal nutrition in Ethiopia (Kabaija and Little, 1987). So that it should be supported by rich feed resources or commercially available sources. According to the result of the current study, the crude protein content of sainfoin hay was 17%. Basically, the lower CP limit required for optimum rumen function is reported to be 7% (Van Soest and Robertson, 1985) and about 6 to 7% dietary CP is required for promoting voluntary intake (Ben Salem et al., 2004). The crude protein content of sainfoin hay (17%) in the current study is more than adequate for optimum rumen function and to promote voluntary feed intake of ruminant animals placed on poor roughage (straw) based feed resource.

For maintaining rumen normal function and production maximization, ruminants require sufficient NDF in their diet. However, the higher NDF in sainfoin hay may limit ruminal fill and intake and nutrient availability because it has a negative correlation with feed digestibility. According to Van Soest (1965) and Singh and Oosting (1992), feeds with NDF content of 45 to 65% are categorized as medium quality. Similarly, McDonald et al. (2002) reported that feeds with high ADF content could lower the availability of nutrient due to the established negative relationship between ADF and digestibility. Hence, the NDF and ADF content of sainfoin hay used in the present study could be considered as higher quality feed than poor tropical roughages used in ruminant animal nutrition. However, the ADL content of sainfoin recorded from the current study appears to be slightly high. The CP, EE, ADF and ADL contents recorded from sainfoin hay in this study were in agreement with that of Guglielmelli et al. (2011), but contradict in ash and NDF content. Rufino-Moya et al. (2019) reported similar ash content of sainfoin hay with that of the results of the current study but lower in NDF, ADF, ADL, and EE and higher content of CP than that of the results of the current study. Variability could be attributed to leaf to stem proportion, accession variation and soil and growth stage. The wheat bran used in the current study is significantly higher in EE content (3.61%) than the others, but low in NDF, ADF and ADL contents. Wheat bran was significantly higher in metabolizable energy. The ash content of the wheat bran used in the current study, was in agreement with that of Mamo et al. (2021) but higher in NDF, ADF and ADL contents. Wheat bran used in the current study contained 16.21% crude protein, the amount of which was lower compared with the values reported by Mamo et al. (2021), Amde (2015) and Shashie et al. (2017).

Noug seed cake used in the current study was relatively low in NDF and ADF content and contained 31.71% CP. According to Lonsdale (1989) feeds that contain crude protein contents of less than 12%, 12-20% and higher than 20%, are classified as low, medium and higher protein source, respectively. Furthermore, feeds with CP content of more than 20% are known as protein concentrate/supplements (Susan, 2003). Hence, the Noug seed cake used in the present study could be classified as protein concentrate/supplement which could satisfy the growth and production requirements of the experimental lambs (Norton, 1982). However, the high market price and unavailability of Noug seed cake are the major limitation.

Sheep under T3 collectively scored higher DM, CP and ME intake than sheep under other treatments. The better intake performance of the groups placed on T3 could be attributed to increased palatability and voluntary intake (Martin et al., 2010; Sheldrick and Thomson, 1982) and nitrogen passage rate to the lower tract of the digestive system (Theodoridou et al., 2011).

Digestibility results of the current study is in line with that of Mamo et al. (2021), who reported better digestibility from groups of Selale sheep supplemented with different levels of either wheat bran, NSC or their combinations compared to that of the non-supplemented groups fed on roughage as a basal diet. The mean DM digestibility obtained from the groups placed on T1 (0% sainfoin) and T3 (20% sainfoin) in the current study are in agreement with that of Mamo et al. (2021). The mean CP digestibility recorded from all the treatment groups of the current study was noted to be higher than (26-84%) that reported by Mamo et al. (2021). The results of NDF digestibility obtained from the present study was found to be higher for the groups placed on T4 (30% sainfoin) showed an increasing trend with increased levels of inclusion of sainfoin, the results of which agreed with that of Mamo et al. (2021). The mean ADF digestibility recorded in the present study was much lower than that of Mamo et al. (2021) as reported for Selale sheep. The higher DM digestibility recorded from the groups fed on the diet containing sainfoin as substitute for NSC compared to that of the control groups could be attributed to the effect of micro-organisms' efficiency and proliferation. Better digestibility is also associated with CP intake level (Singh and Oosting 1992). The consistency of NDF and ADF digestibility exhibited in the present study is in agreement with that of Aschalew and Malede (2013) who reported progressive increment in digestibility with the increase level of supplementation. Such conditions could be attributed to the effect of sainfoin hay inclusion as substitute for NSC. In the present study, sainfoin inclusion level of 10 and 30% resulted in efficient digestibility of DM and ADL.

Getu et al. (2017), reported daily weight gain of 106 g/h from Arsi-Bale sheep supplemented with 206 g DM of Hawassi-83 vine, the value of which is higher than that of the results of the current study. According to the results of the current study, the daily body weight gain of 38 g/h was attained by the groups fed T1 (0%sainfoin) the results of which was in line with that of Abreha et al. (2019). The body weight gain results of the current study is in line with that of Gemechu and Mekasha (2016), who reported comparable performance from Menz sheep fed concentrate mixture on the top of urea treated barley straw as basal diet. The variation in growth performance could be attributed to sheep type, supplement type and level, supplements' chemical composition, pre-treatment feeding status and age of the experimental unit. Krall et al. (1971) reported the higher efficiency (0.7 kg/day) of the groups placed on sainfoin pasture. Marten et al. (1987) in their long-term grazing season study on grazing heifers also recorded higher gain (0.8 kg/day) from groups placed on sainfoin based grazing = Noug cake (38.00%) + wheat bran (50.00%) + molasses (8.54%) + salt (1.00%) + clay soil (0.50%) + lime (1.50%) + urea (0.46%).

Block2 = All ingredients in Block 1 but poultry litter (23.00%) replaced urea;

Block3= All ingredients in Block 1 but fishmeal (24.00%) replaced urea.

Block 1 = Noug cake (38.00%) + wheat bran (50.00%) + molasses (8.54%) + salt (1.00%) + clay soil (0.50%) + lime (1.50%) + urea (0.46%).

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Block 1 = Noug cake (38.00%) + wheat bran (50.00%) + molasses (8.54%) + salt (1.00%) + clay soil (0.50%) + lime (1.50%) + urea (0.46%).

Block2 = All ingredients in Block 1 but poultry litter (23.00%) replaced urea;

Block3 = All ingredients in Block 1 but fishmeal (24.00%) replaced urea.

Barry and Duncan (1984) reported that 63 g/kg DM of CT impede digestibility and 5-8 g/kg DM is the lower limit for the manifestation of its effect. Sheep fed sainfoin containing 60 g CT/kg DM does not show significant impairment in rumen digestion of carbohydrates (Barry and Duncan, 1984). Forage that contains CT exhibited a reduced rumen ammonia due to lower solubility and reduced deamination (Aerts et al., 1999). Mueller-Harvey (2006) stated the condensed tannins efficiency on utilization of urea in recycling in the rumen because of the lower rate of protein degradation and deamination in the rumen. These results are in agreement with that of the present study in that the optimum CT holding sainfoin hay supplement supported for better weight gain than the concentrate fed animals. Despite relatively higher feed intake observed in T3, the noted daily gain and FCE were lower than the rest sainfoin inclusion effects, which resulted into inconsistent trend. The result could be attributed to interaction effect of the ingredients. Similar with the present study result, Li et al. (2024) reported the inconstant trend in weight gain. According to their finding, the daily weight gain is dependent on the ingredient inclusion ratio effect (the protein: fat) than the total supplement amount. Other than the ingredient proportion effect, the available CP protein could affect the consistency trend. Ali et al. (2023) reported the available CP can cause differences in alteration which agreed with the resent result cases. The CP sources in the present study were wheat straw, wheat bran, Noug seed cake and sainfoin hay. All the ingredients' CP could be varied in availability which may result into differences in alteration extent together with the effect of CT in sainfoin.

The relatively higher HCW recorded in the present study is in agreement with that of Getahun et al. (2020). All the results reported by Gemechu and Mekasha (2015) are found to be lower than that of the results of the current study. Variability of the hot carcass weight and dressing percentage could be attributed to animal type/breed, feed conversion efficiency and personnel and material calibration errors. The results of the rib eye area obtained in the present study are in agreement with that of Kiflay et al. (2014). In contrast to the present study result, higher rib-eye area records were presented by Tesema et al. (2013) and Gemechu and Mekasha (2015). Degu et al. (2009) also suggested the contrary result as the level of concentrate inclusion increased the trend of rib eye muscle area increased. The contradicting result could be raised from experimental sheep type and experimental feed and breed.

Compared to the report of Getahun et al. (2020), the lower kidney weight obtained from the present study might be related to the storage of reserve substances such as glycogen as reported by Lawrence et al. (1989). Contrary to the present study, Hirut et al. (2011) and Gemechu and Mekasha (2015) reported progressive increase of non-edible offal with increase in the supplementary levels. Contradictory to their suggestion, absence of the progressive increase of the non-edible offal in the present study could be attributed to sheep type/breed that causes variation on fur weight and horn weight.

Meat quality can be evaluated based on the content of CP, fat, water and ash contents as suggested by Getahun et al. (2020). Worku et al. (2020) in their study recorded 5.8, 5.8 and 5.7% of ash for Gumz, Rotami and Washera sheep, respectively. In contrast to these records, Cirne et al. (2019) recorded lower (1.05%) ash content from South African sheep meat. However, ash content of the experimental sheep of from the present study was lower than Worku et al. (2020) but higher than Cirne et al. (2020) report. The variation in ash content could be due to age effect. Fat deposition exhibited a decreasing trend with increased level of sainfoin inclusion. The significantly higher EE content recorded from the groups fed on T1 could be accumulation of calorie as suggested by Schoonmaker et al. (2010)' who indicated that as the concentrate intake increases, fat deposition increases due to production of more propionate and/or higher glucose in small intestine from non-degradable starch which stimulates insulin production and consequently lipogens. Worku et al. (2020) reported 10.3, 8.8, and 8.6% EE for Gumz, Rutamo and Washera sheep, respectively that contradicts the present EE result. Variation could be attributed to sainfoin chemical content and taken as the progressive sainfoin hay inclusion resulted into a progressive decreased fat deposition.

In the present study, the increase in sainfoin inclusion exhibited a progressive increase in CP% content of the eye muscle. Similar increment results also recorded by Worku et al. (2020) for Gumz, Rutamo and Washera sheep and also by Wati et al. (2019). Mammalian meat is expected to contain 19, 2.5 and 0.65% of CP, fat and total ash (mineral) (Marinova et al., 2005; Toplu et al., 2013), respectively which are contradicting results compared with the current study. From the results again it can be concluded that as the sainfoin inclusion increases, the collective caloric values decreases.

Groups of sheep fed on T1 and T4 had higher water to protein ratio than the others. Despite species variation, Moawad-Mohamed et al. (2013) recorded 3.2 to 3.69 W/P ratio in their study. Brzostowiski et al. (2008) deduced that a desirable water to protein ratios is within a range of 3.89 to 4.18, the results of which are contrary with that of the current study. The variation could be explained in terms of chilling period, the time length between slaughtering and introduction into freezer. However, the relatively lower W/P ratio recorded from the current study is taken as better quality as supported by Daszkiewicz H [16], who reported stated lower W/P ratio is the more desirable because it contributes higher product yield during meat processing. Therefore, muscle of the groups placed on T2 and T3 in the present study could be taken as the better quality.

The significantly higher net income brought by the groups fed on T4 was due to the relatively lower treatment feed cost which resulted from 30% sainfoin inclusion in total DM offered. Profitability of the current study result was in agreement with that of Tesema et al. (2013) for Black-head Ogaden sheep that supplemented with different mixture level of green *Prosopis juliflora* pods and NSC. The reason could be breed, market price, and market season effect.

Conclusion

(1) Inclusion of graded level of sainfoin hay into roughage based ration as substitute for NSC improved nutrient

consumption, total digestibility, and nutrient retention.
(2) The progressive increment in inclusion of sainfoin hay resulted in increased daily gain, FCE and dressing percentage than the control group up to 205 but there was no significant difference on rib-eye area muscle size.
(3) Sainfoin inclusion as substitution for NSC caused reduction in EE, caloric value and inconsistent water to protein ratio but increased the CP% of rib-eye muscle.
(4) Sainfoin inclusion as substitute for NSC increased the MRR.

ABBREVIATIONS

ADF, Acid detergent fiber; **ADL,** acid detergent lignin; **AOAC,** Association Of Officiating Analytical Chemists; **Ca,** calcium; **Cm,** centimeter; **CP,** crude protein; **CSA,** Central Statistical Authority; **CT,** condensed tannin; **CV,** critical value; **D,** day; **DM,** dry matter; **EE,** ether extract; **FCE,** feed conversion efficiency; **FCE,** feed conversion efficiency; **GDP,** gross domestic product; **H,** hour; **HCW,** hot carcass weight; ***IVDMD,*** *in vitro* dry matter digestibility; **Kcal,** kilo calorie; **LS,** level of significant; **LSD,** least significant difference; **MCal,** mega calorie; **ME,** metabolizable energy; **MJ,** mega Joule; **mm,** millimeter; **MRR,** marginal rate of revenue; **N,** nitrogen; **NDF,** neutral detergent fiber; **NI,** net income; **NS,** non-significant; **NSC,** Noug seed cake; **OM,** organic matter; **P,** phosphorus; ***P,*** probability; **REA,** rib eye area; **SAS,** Statistical Analysis System; **TR,** total revenue; **TVC,** total variable cost; **WHC,** water holding capacity; **W/P,** water to protein ratio; **Δ,** symbol for change.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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