

Effect of processed sweet lupin (*Lupinus angustifolius*) grain supplementation on growth performance and socioeconomic feasibility of Doyogena sheep in Ethiopia

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Abstract

Background: The experiment evaluated the effect of supplementing sheep fed natural pasture hay with processed sweet lupin grain on growth performance and its economic feasibility. The finding revealed that use of steamed lupin shown to improve the nutritive value of the grain and sheep performance.

Methods: The experiment was carried out using 24 yearling lambs with initial body weight of 27.53 ± 2.67 kg (mean \pm SD) for 126 days (21 days quarantine, 15 days of adaptation and 90 days growth trial followed by 7 days digestibility trial). The experiment was laid out in a randomised complete block design consisting of four treatments and six blocks. Treatments comprised the feeding of natural pasture hay ad libitum + concentrate mix 440 g (T1), natural pasture hay + 440 g/day roasted, coarsely ground sweet lupin grain (T2), natural pasture hay + 440 g/day sweet lupin grain soaked in water for 72 h (T3), natural pasture hay + 440 g/day steamed sweet lupin grain (T4).

Results: There was improvements in total dry matter intake and digestibility coefficients of dry matter, organic matter, crude protein, neutral detergent fibre and acid detergent fibre in sheep supplemented with processed sweet lupin grains compared (T4) by 58.49%, 24.66%, 39.39%, 22.97% and 39.68%, respectively, over the control group. Specifically sheep supplemented with T4 had significantly higher ($p < 0.001$) average daily gain (by 51.04%), feed conversion efficiency (46.34%) and daily weight gain (144.78 g/day) compared to the control treatment, respectively. All processing methods resulted in favourable average daily gain and net return, thus can be employed in feeding systems depending on their availability and relative cost.

Conclusions: Supplementing sheep fed natural pasture hay with 440 g/day steamed sweet lupin grains improved growth performance and fattening economics of

Study Area: The study was conducted in Doyogena district, Ancha Sadicho Peasant Association (PA), Kembata Tembaro Administrative Zone, Southern Ethiopia located 258 km southwest of Addis Ababa, 7016'20"-7030'0"N latitude and 37045'33"-37048'51"E longitude (Ethio-Arc GIS 2019) at an altitude ranging from 1900 and 2748 m.a.s.l. The average annual rainfall was 1400 mm with a bi-modal distribution from February to April and from June to September and the average annual minimum and maximum temperature was 10°C and 16°C, respectively.

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Doyogena sheep compared to T2 (roasted sweet lupin grain), T3 (soaked sweet lupin grain) or the control (T1).

KEYWORDS

growth performance, processed sweet lupin grain, sheep

1 | INTRODUCTION

In Ethiopia, the livestock sub-sector has a significant contribution to the national income and livelihoods of households (Leta & Mesele, 2014). However, the role of the sector towards the country's economy has not been in line with its potential. This is associated with several complex and inter-related factors of which inadequate feed is the major one (Osti, 2020). Major feed resources for ruminants in the country include natural pasture, crop stubble, road and riverside pasture, crop residues, and agro-industrial by-products (CSA, 2018). Sheep in the highlands depend on communal grazing, fallow lands and crop residues (Kenfo et al., 2018). These feed resources provide insufficient nutrients beyond maintenance requirements leading to low productivity. This situation is aggravated during the dry season when natural pastures are critically deficient in protein and energy content (Kenfo et al., 2018). Thus, supplementation with high nutritive value feed resources is imperative to improve sheep growth performance and productivity in the country.

Sweet lupine (*Lupinus angustifolius* L.) is one of the major crops grown in different soil types. Its growth performance compares better than other lupin species (Tessema, 2017) in all locations. It yields 2.98 t/ha of grain in mid altitudes of Southern Ethiopia (Tessema, 2017) and can be used as an alternative home-grown protein supplement to mitigate livestock feed shortages in the country (Haile et al., 2017). It has a relatively high crude protein (CP) content of 34.35%, digestible organic matter (DOM) content of 86.28% and a relatively low alkaloid content (Yenesew et al., 2015). The alkaloid content of sweet lupin was found to be 112 mg/kg DM while the white local varieties has high 10,231 mg/kg DM as reported by Likawent et al. (2012). Besides, a study conducted using sweet lupin grain as a supplement with 290 g/head per day on Washera sheep showed that the animals gained 74 g/head per day and 5.1 kg/head in a trial of 69 days (Yeheyis et al., 2012). Supplementation of sweet lupin has potential to improve the efficiency of utilisation of available roughage feed resources (Rodrigues et al., 2017).

It has been reported by Likawent et al. (2012) that the high alkaloid content of local lupin has negative impact on the utilisation of seeds as livestock and human food.

Soaking after roasting, boiling, germination, fermentation and alkaline treatment are practices that have been reported to reduce anti-nutritional factors in diets (Joray et al., 2007). The practice of processing sweet lupin seed as a supplement for fattening lambs is relatively new in Ethiopia, but it has not been studied. Therefore, this study conducted an on-farm evaluation to determine promising pro-

cessing methods of sweet lupin on feed intake, nutrient digestibility and growth performance of Doyogena sheep in Ethiopia.

2 | MATERIAL AND METHODS

2.1 | Farmer selection

The study was undertaken on-farm. The district comprises of 4 urban and 13 rural PA. Ancha Sadicho, one of the rural PA (peasant association - a lower-level administrative hierarchy in Ethiopia), was purposively selected based on availability of sufficient sheep populations as well as willingness and interest of farmers to participate. Subsequently, 8 volunteer farmers who owned more than 10 sheep were selected from four different villages within the PA (Figure 1). Selection of the farmers was facilitated by agricultural development agents. Three growing intact male lambs were selected from the flock of each farmer considering uniformity in physical performance, health status and body weight. Before the commencement of the experiment, farmers were trained on experimental procedures.

2.2 | Experimental animals and their management

Twenty-four yearling intact male Doyogena sheep (27.53 ± 0.554 kg live weight) were quarantined for 21 days to adapt them to temporary shelter built on-farm by participant farmers and to observe their health status. During this period, sheep were vaccinated against ovine pasteurellosis, sheep pox, blackleg and anthrax with 1 ml ovine pasteurellosis vaccine, 1 ml sheep pox vaccine and 1/2 ml anthrax vaccine per sheep respectively. Sheep were dewormed against internal parasites (flat worms and round worms), drenched with anthelmintics and sprayed against external parasites (tick and mange) before the beginning of the experiment.

The experimental design was a randomised complete block design. Experimental sheep were blocked into six groups each group with four sheep, based on their initial body weight (BW) and randomly assigned to one of the four dietary treatments. Before commencement of the experiment, initial BW was measured and recorded as an average of three consecutive weightings after overnight fasting. The four villages had equal number of sheep for each treatment. Live weight was measured gravimetrically using a portable spring-dial hoist scale (Camry, NTB, Camty company, China), with a capacity of 100 kg and precision of 50 g. Animals weight measurements were taken in the



FIGURE 1 Fattening Doyogena sheep with processed sweet lupin supplementation

morning after overnight fasting to avoid variations due to gut fill. Sheep had free access to clean water and salt throughout the experimental period. Experimental animals were managed jointly by farmers and researchers.

2.3 | Experimental feed

Experimental feed consisted of a basal diet of natural grass hay, processed sweet lupin grain and commercial concentrate. The concentrate mix was in proportion of 30% noug seed cake, 35% wheat bran, 34% ground maize grain and 1% salts. Natural pasture hay was obtained from the local market and chopped to 5–15 cm prior to offering. Sweet lupin grain was processed by roasting then grinding, soaking in water for 72 h, or steaming. Roasting was done on a flat plate surface (*Mitad*) by continuously mixing and stirring the seeds to ensure uniformity and until several black spots were observed on seeds. The temperature of template surface was 144°C and the average roasting period was 13 min. Roasted grain was, thereafter, ground in an attrition mill. Each kilogram of raw sweet lupin grain was soaked in 2 L of tap water for 72 h. Raw sweet lupin grains were steamed for 30 min.

2.4 | Experimental design and treatments diets

The experiment was laid down in a randomised complete block design. Experimental animals were blocked into six groups based on their initial body weight (BW), which was determined after two consecutive weights and taking the average weight for each sheep. Then the sheep were and randomly assigned to one of the four dietary treatments using lottery method for treatments as control, natural pasture hay + concentrate mix (T1), natural pasture + 440 g/day roasted, coarsely

ground lupin grain (T2), natural pasture + 440 g/day soaked lupin grains (T3) and natural pasture + 440 g/day steamed lupin grain (T4).

2.5 | Feeding trial

The experimental sheep were adapted to experimental diets for 15 days and actual data collected for 90 days. Treatment feeds were offered to individual sheep twice daily at 10:00 am and 5:00 pm in equal portions. Refusals were collected, sampled and weighed daily per animal and pooled on treatment basis for laboratory analysis. Daily feed intake of each sheep was recorded. Experimental sheep were weighed on the first day of the feeding trial and subsequently at weekly intervals after overnight fasting.

Feed conversion efficiency (FCE) was calculated as follows:

$$\text{Feed conversion efficiency} = \frac{\text{Average daily live weight gain (g)}}{\text{Average daily feed intake (g)}} \quad (1)$$

2.6 | Digestibility trial

The digestibility trial was conducted after 90 days of the feeding trial. It comprised of 3 days for animals to adapt to carrying the faecal collecting bags followed by 7 days of faeces collection. Faeces were collected and weighed every morning for each animal before offering feed and water. It was kept in airtight plastic containers and stored at -20°C in a deep freezer refrigerator up to completion of the digestibility trial. Feed offered, and refusals were collected, weighed and recorded every morning. At the end of the digestibility trial, faecal samples were pooled for each sheep, thawed, thoroughly mixed and 20% subsample and dried at 60°C for 48 h. Faecal samples for determination of dry matter

digestibility were air-dried and kept until oven drying at 105°C. Partially dried faeces were ground to pass through a 1 mm sieve and stored until laboratory analysis.

2.7 | Chemical analysis

Representative samples of feed offered, refusals, and faecal samples were analysed at the ILRI Animal Nutrition Laboratory in Addis Ababa. Samples of feed offered, refusals and faeces were dried at 60°C for 48 h in a forced draft oven and ground to pass through 1 mm sieve using a Wiley mill, packed into paper bags and stored pending further laboratory works. They were analysed for dry matter (DM), ash, crude protein (CP), neutral detergent fibre (NDF), acid detergent fibre (ADF), acid detergent lignin (ADL), in vitro organic matter digestibility (IVOMD) and metabolisable energy (ME) using the sweet lupin near-infrared reflectance spectroscopy (NIRS) prediction equation (Glencross et al., 2008). Prior to scanning using NIRS, ground samples were dried overnight at 60°C to standardise moisture conditions. Crude protein (%) of feed samples was determined by multiplying the N content of the samples with the conversion factor of 6.25. The metabolisable energy of feeds offered was estimated from digestible energy (DE) and IVOMD using regression and summation equations developed by NRC (2001): Digestible energy was obtained using the formula:

$$\begin{aligned} DE &= (0.01 \times (OM/100) \times (IVOMD + 12.9) \times 4.4) - 0.3, \\ ME \text{ (mcal/kg)} &= 0.82 \times DE \text{ was calculated and converted to kilogram} \\ ME \text{ (MJ/kg)} &= 4.184 \times ME \text{ (mcal/kg)}. \end{aligned} \quad (2)$$

where DE is digestible energy; IVOMD is in vitro organic matter digestibility; ME is metabolisable energy; MJ is megajoule; mcal is megacalorie; kg is kilogram.

2.8 | Partial budget analysis

Partial budget analysis was used to determine the profitability of the feeding regime on the experimental sheep. The purchase price of experimental feed was recorded and also market price of experimental sheep at the beginning and at the end of the experiment was assessed in the local animal market and estimated by experienced sheep dealers in the district. The partial budget analysis was calculated from the variable costs and benefits. At the same time, three experienced local sheep dealers were selected purposively for estimating the selling price of each experimental sheep before and after supplementation and the average of those three-estimation prices was taken. Then, the variable costs were calculated from supplementary feeds, which are provided for each experimental sheep treatment costs. The total returns (TR) was determined by calculating the difference between the estimated selling prices and purchasing price of experimental sheep and the cost of the supplemented feed. Net return (NR) was calculated as $NR = TR -$

TVC. The change in net return (ΔNR) was calculated as the difference between a change in total return (ΔTR) and the change in total variable costs (ΔTVC) (supplemented feed), $\Delta NR = \Delta TR - \Delta TVC$. The marginal rate of return (MRR) measures the increase in net income (ΔNR) associated with each additional unit of expenditure (ΔTVC) was calculated as $MRR = (\Delta NR / \Delta TVC) \times 100$.

To determine the economic return of the feeding trial, partial budget analysis was calculated according to Upton (1979), as follows:

$$\begin{aligned} \text{Total return (TR)} &= \text{selling price} - \text{purchasing price of the sheep,} \\ \text{Net return (NR)} &= \text{TR} - \text{total variable cost (TVC),} \\ \text{Change in net return (NR)} &= \text{NR of supplemented treatment} - \text{NR} \\ &\quad \text{of controlled treatment,} \\ \text{Change in total variable cost (TVC)} &= \text{TVC of supplemented} \\ &\quad \text{treatment} - \text{TVC of controlled treatment.} \end{aligned}$$

To measure the increase in net return associated with each additional unit of expenditure, the marginal rate of return (MRR) was calculated as $MRR = NR / TVC$.

2.9 | Statistical analysis

All data from the trial experiments, on feed intake, feed quality (nutritional content of feed) and live weight gain, FCE, and others were summarised and managed with MS-Excel (2010) and then subjected to analysis of variance (ANOVA) in a randomised complete block design using the general linear model procedure of SAS (2002) version 9.00. Individual differences between means had been tested using Duncan's multiple range test.

3 | RESULTS

3.1 | Chemical composition of experimental feeds

The result of the chemical composition of the experimental feeds is presented in Table 1. There was higher amount of OM, CP, ME and IVOMD in the conc. mix, RCGSLG, SSLG and StSLG feed components as compared to hay feed, the NDF, ADF and ADL as well as hemicelluloses components of hay were higher than other feed components as shown in the table.

3.2 | Dry matter and nutrient intake

The DMI of hay in T4 was significantly higher than T1 (Table 2). The DMI of lupin grains was significantly higher ($p < 0.05$) than the concentrate mix. The total DMI and OMI in T4 was significantly higher ($p < 0.05$) than T1, which has shown a 2.66% increment. NDF intake of T4 was significantly higher ($p < 0.05$) than the control. Sheep in T2 and T3 had no significance ($p > 0.05$) difference in terms of total DMI, OMI and NDF except CP and ADF intakes where these nutrients

TABLE 1 Chemical composition of experimental feed

| Nutrient parameter | Treatment feed offered (%) | | | | |
|--------------------|----------------------------|-----------|--------|------|-------|
| | Hay | Conc. mix | RCGSLG | SSLG | StSLG |
| DM (%) | 91.2 | 92.3 | 93.4 | 93.3 | 93.1 |
| Ash (%DM) | 14.3 | 5.6 | 4.4 | 4.5 | 3.9 |
| OM (%DM) | 85.7 | 94.4 | 95.6 | 95.5 | 96.1 |
| CP (%DM) | 6.8 | 17.6 | 36.2 | 39.3 | 28.2 |
| NDF (%DM) | 66.7 | 32.1 | 30.2 | 30.3 | 38.7 |
| ADF (%DM) | 40.9 | 16.3 | 16.8 | 14.7 | 25.3 |
| ADL (%DM) | 6.7 | 3.9 | 2.0 | 1.1 | 1.6 |
| ME (MJ/kg) | 6.9 | 9 | 11.3 | 11.3 | 10.2 |
| IVOMD (%) | 47.7 | 62.8 | 80.6 | 81.7 | 72.8 |
| Hemicellulose | 25.8 | 15.8 | 13.4 | 15.6 | 13.4 |

DM, dry matter; OM, organic matter; CP, crude protein; NDF, neutral detergent fibre; ADF, acid detergent fibre; ADL, acid detergent lignin; con. mix, concentrate mixture (30%, 35%, 35% and 1% noug seed cake, coarsely ground maize grain, wheat bran and salt, respectively); RCGSLG, roasted and coarsely ground sweet lupin grain; SSLG, soaked sweet lupin grain; StSLG, steamed sweet lupin grain; ME, metabolisable energy; IVOMD, in vitro organic matter digestibility.

found to be significant between these treatments. Sheep in the T3 and T4 had significantly less ($p < 0.05$) ADF intake compared to sheep in the T1.

3.3 | Dry matter and nutrients digestibility

The DM, OM, CP, NDF and ADF digestibility of the lupin groups was significantly higher ($p < 0.05$) than the control as indicated in Table 3. There was an improvement of 58.49%, 24.66%, 39.39%, 22.97% and

TABLE 2 Dry matter and nutrient intake of Doyogena lambs fed natural pasture hay basal feed, supplemented with processed sweet lupin grain

| Dry matter intake | Treatments | | | | SEM | p Value |
|-------------------------|----------------------|----------------------|----------------------|---------------------|------|---------|
| | T1 | T2 | T3 | T4 | | |
| Hay DMI | 378.79 ^b | 385.14 ^{ab} | 382.21 ^{ab} | 395.8 ^a | 2.81 | 0.1590 |
| Supplement DMI | 405.23 ^d | 411.04 ^a | 410.56 ^b | 409.61 ^c | 0.41 | <0.0001 |
| Total DMI | 784.76 ^b | 796.18 ^{ab} | 792.77 ^{ab} | 805.46 ^a | 2.92 | 0.0808 |
| DMI (g/kg W) | 53.60 | 50.46 | 51.43 | 51.53 | 1.84 | ns |
| Nutrient intake (g/day) | | | | | | |
| Total ASH | 84.03 ^b | 79.74 ^c | 80.16 ^c | 99.46 ^a | 1.71 | <0.0001 |
| Total OM | 770.83 ^b | 782.51 ^{ab} | 779.32 ^{ab} | 794.77 ^a | 2.94 | 0.0233 |
| Total CP | 105.68 ^d | 187.68 ^b | 200.97 ^a | 153.59 ^c | 7.67 | <0.0001 |
| Total NDF | 418.24 ^b | 414.52 ^b | 412.82 ^b | 459.75 ^a | 4.4 | <0.0001 |
| Total ADF | 241.57 ^{bc} | 246.18 ^b | 236.07 ^c | 288.82 ^a | 4.49 | <0.0001 |

^{a-d}Means with different superscript within a row differ ($p < 0.05$) and ($p < 0.01$).

BW, body weight of live animal; DMI, dry matter intake; NS, non-significant; OMI, organic matter intake; NDF, neutral detergent fibre intake; ADF, acid detergent fibre; ADL, acid detergent lignin; CP, crude protein intake; SEM, standard error mean; SL, significant level; T1, concentrate mixture; T2, roasted and coarsely ground sweet lupin grain; T3, soaked sweet lupin grain; T4, steamed sweet lupin grain; ns, non-significant.

TABLE 3 Apparent nutrient digestibility coefficients of treatment feeds in Doyogena sheep fed on hay and supplemented with processed sweet lupin grain

| | Treatments | | | | SEM | p Value |
|-----|-------------------|-------------------|-------------------|-------------------|-------|---------|
| | T1 | T2 | T3 | T4 | | |
| DM | 0.53 ^d | 0.78 ^b | 0.69 ^c | 0.84 ^a | 0.029 | <0.0001 |
| OM | 0.73 ^d | 0.87 ^b | 0.80 ^c | 0.91 ^a | 0.028 | <0.0001 |
| CP | 0.66 ^c | 0.92 ^a | 0.84 ^b | 0.92 ^a | 0.063 | <0.0001 |
| NDF | 0.74 ^d | 0.86 ^b | 0.79 ^c | 0.91 ^a | 0.039 | <0.0001 |
| ADF | 0.63 ^d | 0.80 ^b | 0.72 ^c | 0.88 ^a | 0.063 | <0.0001 |

^{a-d}Means within a row with different superscript differ ($p < 0.01$).

SEM, standard error of means; DM, dry matter; CP, crude protein; OM, organic matter; NDF, neutral detergent fibre; ADF, acid detergent fibre; SL, significance level; T1, concentrate mixture; T2, roasted and coarsely ground sweet lupin grain; T3, soaked sweet lupin grain; T4, steamed sweet lupin grain.

39.68% increment in T4 over T1 (the control group). Regarding the CP digestibility, there was no significant difference between T2 and T4 groups. However, there was significant ($p < 0.05$) difference between T2 and T3 in terms of all nutrients' digestibility.

3.4 | Bodyweight change and feed conversion efficiency

Of the parameters measured related to body weight, the average daily gain and FCE of T4 were significantly higher ($p < 0.05$) than that of T1 (Table 4). These parameters showed 51.04% and 46.34% increments, respectively, in T4 over the control. However, there was no significant difference between T2 and T3 in the above parameters.

TABLE 4 Bodyweight parameters and feed conversation efficiency of Doyogena sheep fed on natural pasture hay and supplemented with processed sweet lupin grain

| Parameters | Treatment | | | | SEM | p Value |
|------------|--------------------|---------------------|---------------------|--------------------|-------|---------|
| | T1 | T2 | T3 | T4 | | |
| IBW (kg) | 27.4 | 28.16 | 28.23 | 26.38 | 0.55 | 0.6283 |
| FBW (kg) | 36.08 | 39.88 | 38.83 | 39.41 | 0.86 | 0.4234 |
| ADG (Kg) | 0.096 ^b | 0.130 ^{ab} | 0.117 ^{ab} | 0.145 ^a | 0.006 | 0.0467 |
| BWC (kg) | 8.71 ^b | 11.72 ^{ab} | 10.56 ^{ab} | 13.03 ^a | 0.58 | 0.0467 |
| FCE | 0.123 ^b | 0.163 ^{ab} | 0.148 ^{ab} | 0.180 ^a | 0.008 | 0.0822 |

^{a-b}Means within rows with different superscripts differ ($p < 0.01$).

IBW, initial body weight; FBW, final body weight; BWC, body weight change; ADG, average daily weight gain; FCR, feed conversion efficiency; SEM, standard error of means; NS, non-significant; SL, significance level; kg, kilogram; T1, concentrate mixture; T2, roasted and coarsely ground sweet lupin grain; T3, soaked sweet lupin grain; T4, steamed sweet lupin grain.

3.5 | Partial budget analysis

Partial budget analysis of Doyogena sheep fed on hay basal diet and supplemented with different forms of processed lupin grain is given in Table 5. All lupin supplemented groups tended to have higher net returns over the control feed sheep groups as shown in the table.

4 | DISCUSSION

It had been stated that CP content ranging between 7% and 7.5% is required to satisfy ruminant microbial demands for nitrogen that would provide sufficient CP for the maintenance requirement of the animals (Van Soest, 1982). The CP content of natural pasture hay in the current finding was lower than the previously reported (Ali et al., 2019) from natural pasture hay but higher than 3.88%, 5.28% and 6.45% reported by Mekuriaw and Asmare (2018), Dejene (2017) and Demoze (2020), respectively, in different parts of Ethiopia. Nevertheless, the observed CP content of natural grass hay used in this on-farm feeding trial was found to be slightly below the maintenance requirements of ruminant animals (sheep). The current CP content in the natural pasture or hay indicates that it requires supplementation with better quality feed to meet not only maintenance requirements but also productivity of animals. On the other hand, the CP content of roasted and coarsely ground sweet lupin grain is high, which enable it to be used to supplement sheep fed poor basal diet. Thus, the use of lupin in the current study is one of the strategies that can mitigate shortage of protein for ruminants in developing countries.

4.1 | Dry matter and nutrient intake

The total dry matter and nutrient intakes of sheep in the current study improved by supplementation of processed lupin. This is what has been supposed to be obtained in such kinds of studies as the main target of

use of protein feeds is to improve the intake of dry matter and nutrients intakes. The dry matter intake normalised for live weight of sheep was not negatively affected by the dietary treatment. That means feeding lupin grains did not affect the palatability of sheep, instead it positively influenced the overall performance of animals. This finding is in agreement with Yilkal et al. (2014) and Yeheyis et al. (2012) reported for supplementation with different forms of processed lupin (*Lupinus albus*) grain in hay-based feeding of Washera sheep. Moreover, in the current experiment, the different legume and processing methods did not affect the performance of lambs' performances (Lestingi et al., 2019). On the other hands, Tefera et al. (2015) also reported that supplementation of processed sweet lupin grain improved body weight changes and carcass yield of lambs in Ethiopia. The inconsistency of findings might be related to the types of basal diet used and processing methods of lupin grains in respective studies.

4.2 | Dry matter and nutrients digestibility

The findings showed an increment in the digestibility of nutrients particularly in T4. This improvement in nutrient digestibility in T4 means that steaming lupin grains decreased the anti-nutritional factors, which otherwise might have influence digestibility of nutrients in the grain. The effect of processing and its importance in decreasing anti-nutritional values has been also reported by other researchers earlier (Yilkal et al., 2014; Likawent et al., 2012) who reported that the digestibility of nutrients of lupin grains improves by several physical treatments. Animals in T2 and T3 had shown intermediate results in both final body weight and FCE. The improvement in weight gain and FCE in T4 observed in the current result might be due to the increase in nutrient supply as a result of the increase in digestibility. This is in agreement with Yilkal et al. (2014) and Yeheyis et al. (2012) studies on lupin grains. The improvement in the total net return suggests that the use of steamed lupin grain is a reliable option to replace the expensive commercial concentrate in meat production in Ethiopian rural areas. Steaming grains is high-demanding process for water and energy, which are limited in the rural areas of Ethiopia. To expand the practice of use of steamed lupin grain, optimising this process (decreasing the duration, temperature and amount of water for steaming) should be identified before large-scale promotion of steaming as a process to improve the nutritive value of lupin grains. However, Arfaoui et al. (2020) stated that supplementation of sweet lupin for Barbarin Lamb had no significant effect on total dry matter and water intakes, average daily gain, diet digestibility and microbial synthesis. The inconsistency of findings might be related to genetic variation of sheep, environmental conditions of the animals and management of animals.

4.3 | Partial budget analysis

The marginal rate of return or ratio for supplemented sheep in T2 and T4 was 3.497 and 53.357ETB (1.10 USD), respectively. The result

TABLE 5 Partial budget and marginal rate of return analysis for Doyogena sheep supplemented with processed sweet lupin grain on hay-based feeding

| Parameters | Treatments | | | |
|--------------------------------------|------------|---------|--------|--------|
| | T1 | T2 | T3 | T4 |
| Purchase price of sheep (ETB/head) | 2025.0 | 1952.8 | 2147.2 | 2175.0 |
| Total hay consumed (kg/head) | 34.9 | 35.5 | 35.2 | 36.5 |
| Feed cost for hay (ETB/head) | 102.4 | 104.1 | 103.3 | 107.0 |
| Total concentrate consumed (kg/head) | 50.5 | 50.5 | 50.5 | 50.5 |
| Cost for concentrates (ETB/head) | 480.0 | - | - | - |
| Cost of feed (ETB/kg) | - | 333.0 | 333.0 | 333.0 |
| Total feed cost (ETB/head) | 582.4 | 437.1 | 436.5 | 440.0 |
| Gross income (ETB/head) | 4413.9 | 5816.7 | 6127.8 | 6383.3 |
| Total return (ETB/head) | 1806.5 | 3426.8 | 3544.1 | 3768.4 |
| Total variable cost (ETB/head) | 1120.0 | 2133.3 | 2458.3 | 2458.3 |
| Net return (ETB/head) | 686.5 | 1293.5 | 1085.7 | 1310.0 |
| Δ NR | - | 1147.01 | 45.45 | 223.57 |
| Δ TVC | - | 327.96 | 71.27 | 4.19 |
| MRR (%) | - | 3.497 | 0.637 | 53.357 |

ETB, Ethiopian Birr; Δ NI, change in net income; Δ TVC, change in total variable cost; MRR, marginal rate of return; T1, concentrate mixture; T2, roasted and coarsely ground sweet lupin grain; T3, soaked sweet lupin grain; T4, steamed sweet lupin grain.

achieved in the present study was higher than 1.22 ETB (0.025 USD) reported by Amanie et al. (2017) but lower than sheep supplemented with soaked sweet lupin grain (T3). This might be due to variations in the purchasing price of sheep, current market situation and selling price of sheep, variations in sheep breeds used and differences in basal diets and supplements used in different experiments.

5 | CONCLUSION

From the current finding, it is understood that steamed lupin grains are more suitable and economical as compared to other types of lupin processing and presumed to be good replacement for commercial concentrate mixed to fattening sheep. The supplements used in this study showed increment in an average daily gain and net return and thus can be used in feeding systems depending on their availability and relative costs. The use of steamed lupin improves the nutritive value of the grain and sheep performance in the current study. For wider use of steamed lupin in the area, the simplification of the steaming process of lupin grains should be studied prior to the final recommendation of this treatment.

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CONFLICT OF INTEREST

The authors declare that they have no conflict of interest.

ETHICS STATEMENT

The experiment was conducted according to the experimental animal management of Ethiopian research system.

AUTHOR CONTRIBUTIONS

All the authors contributed in research conceptualisation, experimental design, data collection and data curation, analysis and final draft manuscript writing.

CONSENT FOR PUBLICATION (INCLUDE APPROPRIATE STATEMENTS)

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REFERENCES

Ali, A., Tegegne, F., Asmare, B., & Mekuriaw, Y. (2019). On-farm evaluation of sun-dried *Ziziphus Spina-Christi* leaves substitution for natural

- pasture hay on feed intake and body weight change of Bati goat breeds in Ethiopia. *Tropical Animal Health and Production*, 51(2), 457–463. <https://doi.org/10.1007/s11250-018-1712-6>
- Amanie, H. M. A., Abebaw, L., Mekuriaw, S., Tilahun, Y., Demeke, B., & Molla, L. (2017). Pre extension demonstration of sweet lupin grain feeding for washera sheep fattening at d/mewi watershed of western Amhara Ethiopia. *International Journal of Agricultural Extension*, 5.
- Arfaoui, H., Salem, H., Ben, N. S., Mezni, M., & Abidi, S. (2020). Nutrient Intake, fermentation, digestibility and growth performance of Barbarin lamb supplemented with sweet lupin. *World Journal of Agriculture and Soil Science*, 4(4), 1–5.
- Assefa, E. (2007). *Assessment of production and marketing system of goats in Dale District, Sidama Zone*. University of Hawassa.
- Ayele, S., Urge, M., & Getachew, A. (2017). Feed intake, digestibility, growth performance and blood profiles of three Ethiopian fat tail hair sheep fed hay supplemented with two levels of concentrate supplement. *Open Journal of Animal Sciences*, 7, 149–167. <https://doi.org/10.4236/ojas.2017.72013>
- CSA. (2018). Agricultural sample survey, Report on livestock and livestock characteristics (private peasant holdings). In *the Federal Democratic Republic of Ethiopia*. Addis Ababa: Central Statistical Authority.
- Dejene, N. (2017). Effect of supplementing the leaves of *Balanites aegyptiaca* and maize grain on growth performance and economic return of indigenous goats in Gamogofa zone M.Sc. thesis, Hawassa Un.
- Demoze, Y. (2020). Effects of supplementing noug seed cake and chickpea chaff mix on feed intake, body weight change, and carcass characteristics of Semien sheep fed on natural pasture hay. MSc thesis.
- Endalew, M., Mekuriaw, Y., Firew, T., & Asmare, B. (2019). Evaluation of fodder biomass yield of hydroponically-grown barley and oats and the effects on intake, digestibility and weight gain of Washera sheep when fed as a supplement to a basal diet of natural pasture hay in Ethiopia. *Tropical Grasslands-Forrajes Tropicales*, 7(5), 519–526. [https://doi.org/10.17138/TGFT\(7\)](https://doi.org/10.17138/TGFT(7))
- Erbas, M., Certel, M., & Uslu, M. K. (2004). Some chemical properties of white lupine seeds (*Lupinus albus*) Turkey. *Food Chemistry*, 89, 341–345.
- Getachew, P. (2009). *Chemical composition and the effects of traditional processing on nutritional composition of Gibto (Lupinus albus L.) grown in Gojam area*. MSc thesis, Addis Ababa University.
- Glencross, B. D., Hawkins, W. E., Evans, D., Rutherford, N., McCafferty, P., Dods, K., & Sipsas, S. (2008). Assessing the implications of variability in the digestible protein and energy value of lupin kernel meals when fed to rainbow trout, *Oncorhynchus mykiss*. *Aquaculture*, 277, 251–262.
- Haile, M., Agraw, A., Lijalem, A., Shigdaf, M., & Tilahun, Y. (2017). Pre-extension demonstration of sweet lupin grain feeding for washera sheep-fattening at d/mewi watershed of western Amhara Ethiopia. *International Journal of Agricultural Extension*, 5(3), 71–73.
- Haile, T., & Emire, S. (2010). Chemical composition, physicochemical and functional properties of lupin (*Lupinus albus*) seeds grown in Ethiopia. *African Journal of Food Agriculture, Nutrition and Development*, 10(8), 3029–3046.
- Joray, M. L., Rayas-Duarte, P., Mohamed, A., & Van Santen, E. (2007). Coated lupin bean snacks. *Journal of Food Quality*, 30, 267–279. <https://doi.org/10.1111/j.1745-4557.2007.00120.x>
- Kassa, E. (2020). *Effects of local brewery byproduct, noug seed cake (Guizotia abyssinica), and their mixtures of supplementation on feed intake, digestibility, weight gain and economic feasibility of Washera Lambs*. MSc thesis, Bahir Dar Ethiopia.
- Kenfo, H., Mekasha, Y., & Tadesse, Y. (2018). A study on sheep farming practices in relation to future production strategies in Bensa district of Southern Ethiopia. *Tropical Animal Health and Production*, 50(4), 865–874. <https://doi.org/10.1007/s11250-017-1509-z>
- Lestingi, A., Colonna, M. A., Marsico, G., Tarricone, S., & Facciolo, A. M. (2019). Effects of legume seeds and processing treatment on growth, carcass traits and blood constituents of fattening lambs. *South African Journal of Animal Science*, 49(5), 799–809.
- Leta, S., & Mesele, F. (2014). Spatial analysis of cattle and shoat population in Ethiopia: Growth trend, distribution, and market access. *SpringerPlus*, 3, 310.
- Likawent, Y., Claudia, K., Tegegne, F., & Peters, K. J. (2012). Sweet lupin (*Lupinus angustifolius* L.) seed as a substitute for concentrate mix supplement in the diets of yearling Washera rams fed on natural pasture hay as basal diet in Ethiopia. *Tropical Animal Health and Production*, 44, 1255–1261.
- Mekuriaw, Y., & Asmare, B. (2018). Nutrient intake, digestibility and growth performance of Washera lambs fed natural pasture hay supplemented with graded levels of *Ficus thonningii* (Chibha) leaves as replacement for concentrate mixture. *Agriculture & Food Security*, 7, 30.
- Osti, N. P. (2020). Animal feed resources and their management in Nepal. *Journal of Scientific Agriculture*, 4, 2–14.
- Prandini, A., Morlacchini, M., Moschini, M., Fusconi, G., Masoero, F., & Piva, G. (2005). Raw and extruded pea (*Pisum sativum*) and lupin (*Lupinus albus* var. Multitalia) seed as protein sources in weaned piglets' diets: Effect on growth rate and blood parameters. *Italian Journal Animal Science*, 4, 385–394.
- Rodrigues, R. C., Melo, M. A., Cardoso Sanchês, S. S., dos Santos Araújo, J., Martins Rodrigues, M., Ribeiro de Jesus, A. P., Pinheiro Amorin, S. E., Alves Araújo, R., Ribeiro Araújo, I. G., & Nunes Parente, H. (2017). Supplementation of sheep with increasing levels of crude protein: performance, animal behavior, and contamination and spread of nematode larvae in *Brachiaria brizantha* 'Xaraés' pasture. *Network of Scientific Journals*, 38(1), 369–380.
- Tarawali, S. (2011). Pathways for sustainable development of mixed crop-livestock systems: Taking livestock and pro-poor approach. *Livestock Science*, 139, 11–21.
- Tefera, G., Tegegne, F., Mekuriaw, Y., Melaku, S., & Tsunekawa, A. (2015). Effects of different forms of white lupin (*Lupinus albus*) grain supplementation on feed intake, digestibility, growth performance, and carcass characteristics of Washera sheep fed Rhodes grass (*Chloris gayana*) hay-based diets. *Tropical Animal Health and Production*, 47(8), 1581–1590. <https://doi.org/10.1007/s11250-015-0901-9>
- Tessema, F. (2017). Biomass Yield and Nutritive Value of Sweet Lupine in Mid Altitudes of Lemo District, Hadiya Zone, Southern Ethiopia, School of Graduate Studies, Woliata Sodo University, Woliata, Ethiopia.
- Tolera, A., Yami, A., & Alemu, D. (2012). Livestock feed resources in Ethiopia: Challenges, opportunities and the need for transformation. Addis Ababa, Ethiopia: Ethiopia Animal Feed Industry Association.
- Upton, M. (1979). *Farm management in Africa: The principle of production and planning* (pp. 282–298). Great Britain: Oxford University Press.
- Van Soest, P. J. (1994). *Nutritional ecology of the ruminant* (2nd ed). Ithaca, New York: Cornell University Press.
- Van Soest, P. J. (1982). *Nutritional ecology of the ruminant* (p. 373). Corvallis, Oregon, USA: O and B Books, Inc.
- Yeheyis, L., Kijora, C., Melaku, S., Anteneh, G., & Peters, K. J. (2010). White lupin (*Lupinus albus* L.), the neglected multipurpose crop: Its production and utilization in the mixed crop-livestock farming system of Ethiopia. *Livestock Research for Rural Development*, 22, 22.
- Yeheyis, L., Kijora, C., Van Santen, E., Wink, M., Danier, J., & Peters, K. J. (2012). Crude protein, amino acid, and alkaloid contents of annual sweet lupin (*Lupinus* spp. L.) forage and seeds are grown in Ethiopia. *Experimental Agriculture*, 48(3), 414–427. <https://doi.org/10.1017/S0014479712000026>
- Yeheyis, L., Kijora, C., Wink, M., & Peters, K. J. (2011). Effect of a traditional processing method on the chemical composition of local white lupin (*Lupinus albus* L.) seed in north-western Ethiopia. *Zeitschrift Fur Naturforschung - Section C Journal of Biosciences*, 66C(7–8), 403–408. <https://doi.org/10.1515/znc-2011-7-812>

- Yenesew, A., Abel, A., Molla, T., Shiferaw, D., Yihewew, G. S., Likawent, Y. A. A., & Dessalegn, M. (2015). Best fit practice manual for sweet lupin (*Lupinus Angustifolius* L.) production. Capacity building scaling up of evidence-based best practices in agricultural production in Ethiopia, Working Paper No. 11.
- Yilkal Tadele Yoseph, M. F. T. (2014). Supplementation with different forms of processed Lupin (*Lupinus albus*) grain in hay based feeding of Washera sheep: Effect on feed intake, digestibility body weight, and carcass parameters. *Journal of Biology, Agriculture, and Healthcare*, 4.

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