Abyss. J. Sci. Technol. Vol. 7, No. 1, 2022, 21-28
ISSN 2616 – 4728 (Online); 2616 – 471X (Print)

Abyssinia Journal of Science and Technology

Effect of Feeding Sweet Blue Lupin (*Lupinus angustifolius* L.) Haulm and Concentrate Mixture on Growth Performance and Carcass Characteristics of Washera Lambs

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ABSTRACT

An experiment was conducted to evaluate the feeding value of graded level of sweet blue lupin haulm and concentrate mixture in the diets of lambs. For the feeding trial, twenty-four yearling Washera lambs with initial body weight of 24.6 kg ± 0.57 were used. The design of the experiment was randomized complete block design. The four experimental feeds were sweet blue lupin haulm to concentrate mixture ratio of 0:453 g, 251 g:362 g, 503 g:272 g and 754 g:181 g per day per head, respectively. Natural pasture hay was used as a basal diet. Results showed that supplementation of sweet blue lupin haulm and concentrate mixture significantly increased total dry matter, crude protein and organic matter intakes. Supplementation of sweet blue lupin haulm and concentrate mixture improved the digestibility of crude protein by 4%. Average daily weight gain was higher for the groups supplemented by sweet blue lupin haulm and concentrate mixture (68.7-87.4 g/day). Carcass parameters were slightly lower for lambs supplemented with higher level of sweet blue lupin haulm, while those supplemented with concentrate mixture and up to 40% sweet blue lupin haulm did not show significant difference. It was concluded that supplementing of mixture of 80% or 60% concentrate mixture with 20% or 40% sweet blue lupin haulm, respectively, in natural pasture hay-based diet can serve as locally available protein source to partially substitute commercial concentrate feeds for Washera lambs in Ethiopia.

Keywords: Carcass, Digestibility, Nutrient intake, Sweet blue lupin haulm, Weight gain.

INTRODUCTION

Shortage of feed both in terms of quality and quantity is the primary limiting factor for higher production and productivity of small ruminants in most parts of Ethiopia (Solomon et al., 2010). In particular, feeding medium energy and high protein diets is a means of improving feed conversion efficiency by improving the growth of sheep without incurring additional feeding costs (Gadissa et al., 2021). Furthermore, supplementation of crop residues with readily fermentable energy and protein concentrate supplements improves their utilization by the animals (Ermias et al., 2013). Thus, provision of appropriate supplementary feedstuffs would be the best alternative strategy to improve nutritional problems and achieve better productivity of sheep by smallholder farmers in Ethiopia (Abate & Melaku, 2009). For instance, sweet blue lupin seed could be used as an alternative home-grown protein source in sheep feeding (Yeheyis et al., 2012).

Lupin is an old crop and grown in north-western Ethiopia. According to Yeheyis et al. (2010) the local white lupin in Ethiopia is a very important traditional multipurpose crop being grown in the mixed crop livestock farming system. The same authors reported that under traditional management system the average grain yield of this crop is 1.67 t/ha. However, the use of the crop as human food and livestock feed is limited due to its bitter taste attributed to its relatively high alkaloid content.

On the other hand, to alleviate the alkaloid content of traditional white lupin, an experiment conducted on sweet lupin adaptation in northwestern Ethiopia showed that sweet annual lupins are adaptive and productive in the traditional lupin growing areas of the country (Yeheyis et al., 2011). In the same study, based on laboratory evaluation, very low alkaloid content of sweet lupins coupled with their relatively better forage and seed crude protein content makes them preferable in production and

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use as a home-grown protein source in livestock feed (Yeheyis et al., 2012).

In Ethiopia commercial concentrate feed is relatively expensive and if it is available, it is in most cases inaccessible for our smallholder farmers (Kosgey et al., 2006). Hence, there is a need to develop an alternative economical home-grown supplement feed for our farmers. Yeheyis et al. (2012) reported that there was no significant difference in body weight gain when 453 g concentrate is substituted with 219 g sweet lupin seed in the diets of Washera sheep. In addition, the crude protein (CP) content was 343.5 g/kg for sweet blue lupin seed as compared to 220.8 g/kg DM for concentrate and there was no palatability problem observed on sweet blue lupin seed used. Thus, from the previous studies it was already indicated that blue lupin seed has a potential to substitute the commercial concentrate supplement feed in Ethiopia.

Lupin is being grown in rotation with cereals on fallow lands and intercropped with maize in northwestern Ethiopia (Yeheyis et al., 2010). However, information regarding the feeding value of sweet lupin haulm as a small ruminant feed is scanty. A “sweet blue lupin haulm” is a residue harvested after the crop has matured and threshed for seed production. It is characterized by hard stems with comparable crude protein content, which could be used as an alternative livestock feed for smallholder farmers. Hence, the present study was undertaken to evaluate the effects of replacing concentrate mixture (CM) with different levels of sweet blue lupin haulm (SBLH) on digestibility, growth performance, and carcass characteristics of Washera lambs.

MATERIALS AND METHODS

Study area:

The study was conducted at Andassa Livestock Research Center which is located in Amhara National Regional State, Ethiopia 22 km south of Bahir Dar. The center is situated 11°29' N latitude and 37°29' E longitude at an altitude of 1730 meters above sea level. The mean annual rainfall is 1434 mm and the mean maximum and minimum temperature ranges from 27.9°C to 13.1°C and humidity ranges from 95% throughout the rainy season to 35% during the dry season. The topography of the area varies from river valley plain to gentle slope grassland. In general, the area is characterized by dark clay soil, which is seasonally water logged.

Experimental feeds and animal management:

The experimental feeds used in the study were natural pasture hay (basal diet), SBLH and CM. Natural pasture hay was collected from the surrounding grazing land reserved for hay production and stored in a shed for subsequent use during feeding and digestibility trials. SBLH was collected from northwestern Ethiopia, South Achefer district after threshing for seed multiplication purpose and transported to the experimental site. Commercial CM was purchased from Tsehay union Gondor town feed mixer plant.

Twenty-four yearling intact male Washera lambs having initial body weight of 24.6 kg ± 0.57 (mean ± SE) were purchased from the local market Adet, which is 45 km southeast of Bahir Dar, Ethiopia. The age of the lambs was determined using the dentition of the animal and information obtained from the owners. After purchase, animals were kept in quarantine for 15 days, during which they were vaccinated against common sheep pox and ovine pasteurellosis, de-wormed against internal parasites with anthelmintic (Tetramizole 600mg), and sprayed with diazinone 60% for external parasites. Then, lambs were transferred to experimental house and data collection was started after a two-week period of adaptation.

Experimental design and treatments:

During the adaptation period, the animals were offered natural pasture hay *ad libitum* and four levels of SBLH and CM in iso-nitrogenous basis for 100 g average daily gain. The feeding trial involved four treatments, which consisted of supplementation of SBLH and CM at the ratio of 0:453 g (T1), 251 g:362 g (T2), 503 g:272 g (T3) and 754 g:181 g (T4) per day per head, respectively. The experiment was a randomized complete block design with six replications where initial body weight was used to make the blocking of experimental animals. Experimental animals from each block were randomly assigned to one of the four dietary treatments (six animals per treatment). They received the basal diet, natural pasture hay, *ad libitum* twice daily in the morning and afternoon. The amount of the basal diet offered was adjusted weekly depending on the level of refusal for each animal. The lambs received one of SBLH and CM in iso-nitrogenous basis as a supplement twice daily at 08:00 and 16:00 hours. Moreover, animals had free access to clean water and salt blocks. Feed offers and refusal was measured daily, and daily intake was calculated as a difference of the daily offer and refusal. Samples of feeds offered and refused were collected daily, bulked and sub-sampled separately on an individual animal basis at the end of the trial for chemical analysis. The body weight of each animal was taken once every 14 days after overnight fasting. The feeding trial lasted for 90 days.

Digestibility trial:

The trial involved three days of adaptation, during which all the lambs became accustomed to carrying a fecal collection bag, followed by seven days of total fecal collection. During the fecal collection period, fecal output of each lamb was collected and weighed daily, before animals were provided their experimental feed. Twenty percent of the daily fecal output of each animal was bulked and stored in an airtight plastic bag at -20 °C. At the end of the digestibility trial, the frozen fecal samples were thawed to room temperature and mixed thoroughly, sub-sampled, and used for chemical analysis.

Carcass evaluation:

At the end of the experiment, five experimental lambs per treatments were randomly selected and slaughtered for carcass evaluation. After overnight fasting, the animals were slaughtered by cutting the jugular vein and the carotid artery. The blood was exhausted into a bucket and weighed. The esophagus was tied off, the animal dressed, and then the thoracic and abdominal cavities were opened. The whole alimentary tract (including esophagus, stomachs, intestines and caecum) and urinary bladder were removed from the cavities, weighed and emptied of their contents. Then the empty gastrointestinal tract was weighed again. The visceral organs and offal including heart, kidney, spleen, liver, lung, head and limbs were removed and weighed. Empty body weight was determined by deducting the gut content from the slaughter weight. In addition, dressing percentage was calculated as a proportion of hot carcass weight to slaughter weight.

Chemical analysis:

Chemical analysis of feed offered, refused, and fecal samples was analyzed at Debre Birhan Agricultural Research Center nutrition laboratory, Ethiopia. Samples of the feed offered, refused and part of the fecal samples were dried at 65 °C in a forced draft oven for 72 h and ground to pass through a 1 mm sieve for subsequent chemical analysis. Dry matter content was determined by drying samples at 105 °C overnight, turning to ash by combusting the dried samples at 550 °C for 4 h and nitrogen (N) with the Kjeldahl method (AOAC, 1990). Crude protein was calculated as nitrogen (N) × 6.25. The neutral detergent fiber (NDF) and acid detergent fiber (ADF) contents were analyzed following the procedures of Van Soest et al., (1991).

Statistical analysis:

The data on feed intake, digestibility, growth performance and carcass characteristics were subjected to analysis of variance in General Linear Model procedure of the Statistical Analysis Software using the following model:

$$Y_{ijk} = \mu + \alpha_i + \beta_j + E_{ijk},$$

Where, Y_{ijk} = the response variable (the observation in α_i treatment and β_j block), μ = overall mean, α_i = treatment effect, β_j = block effect and E_{ijk} = random error. Mean separation was done using the least significance difference test (LSD) in SAS (2002) software.

RESULTS

Chemical composition of experimental feeds:

The CP content of SBLH was almost double than the natural pasture hay while CM has three times more than SBLH (Table 1).

Dry matter and nutrient intake:

The dry matter (DM) and nutrient intake in most measured parameters was found to be significantly different among treatment groups (Table 2.). The DM intake from natural pasture hay showed a decline with increasing level of SBLH, being significantly different ($p<0.001$) in T1 and T2 than T3 and T4. This might be associated with the substitution effect of natural pasture hay by SBLH. However, the total dry matter intake (TDMI) was highest for the animals that were fed a high level of SBLH while the lowest was from animals supplemented with CM alone. Total dry matter intake as percent of live body weight varied significantly ($P<0.001$) among treatment groups.

Digestibility of nutrients:

Except CP, the other nutrients were not significantly different ($P>0.05$) in their digestibility (Table 3). However, the CP digestibility at lower levels of SBLH indicated better value as compared to high level of SBLH inclusion. This might be associated with the lack of availability of balanced protein and energy level at higher SBLH inclusion.

Body weight change and feed conversion efficiency:

There was no difference ($P > 0.05$) in the initial body weight among treatments (Table 4). However, the mean final body weight, average daily weight gain (ADG), and feed conversion efficiency (FCE) decreased significantly ($P < 0.05$) as the level of SBLH is increased up to 60% (754 g/day, T4) of the total supplement feed (Table 4). The mean comparison for the above variables showed a consistent form, with T4 being significantly ($P < 0.05$) lower as compared to the rest of treatment groups.

In most of the experimental period, except for the 2nd week in T2, T3 and T4, there was an increasing trend in body weight change starting from 3rd week (Fig. 1). However, lambs in T3 had slightly higher body weight increment trend than lambs in the highest level of SBLH inclusion.

Table 1: Chemical composition of experimental feeds

Feed types	DM (%)	Percentage of DM					
		Ash (%)	OM (%)	CP (%)	NDF (%)	ADF (%)	ADL (%)
Natural pasture hay	89	6.4	93.6	4.8	74.5	61.1	15.6
SBLH	90	6.3	93.7	7.5	71.1	57.8	12.2
CM mixture	91	8.9	91.1	20.9	33.6	14.4	2.2

SBLH: sweet blue lupin haulm; CM: concentrate mixture; DM: dry matter; OM: organic matter; CP: crude protein; NDF: neutral detergent fiber; ADF: acid detergent fiber; ADL: acid detergent lignin

Table 2: Mean daily dry matter intake (g/day) of Washera lambs fed natural pasture hay as basal diet and supplemented with different levels of sweet lupin haulm and concentrate mixture

Variables	Treatments				SEM	SL
	T1	T2	T3	T4		
Hay DMI (g/day)	470.63^{a}	468.41^{a}	456.12^{b}	443.1^{c}	2.91	**
SBLH DMI (g/day	0.0	216.49^{c}	442.01^{b}	632.1^{a}	2.22	**
CM DMI (g/day)	407.7^{a}	325.8^{b}	244.8^{c}	162.9^{d}	0.0	**
TDMI (g/day)	878.3^{d}	1010.7^{c}	1142.9^{b}	1238.1^{a}	3.98	**
TDMI (%LBW)	2.9^{d}	3.3^{c}	3.7^{b}	4.2^{a}	0.01	**
CP intake (g/day)	107.8^{a}	106.8^{b}	106.2^{b}	102.7^{c}	0.24	**
OM intake (g/day)	811.9^{d}	938.1^{c}	1064.1^{b}	1155.4^{a}	3.73	**
NDF intake (g/day)	487.7^{d}	612.4^{c}	736.3^{b}	834.3^{a}	2.91	**
ADF intake (g/day)	346.3^{d}	458.2^{c}	569.4^{b}	659.5^{a}	2.38	**

Means within a row with different superscripts are statistically significantly different; T1: Natural pasture hay *ad libitum* + 453g CM; T2: natural pasture hay *ad libitum* + 251g SBLH + 362g CM; T3: natural pasture hay *ad libitum* +503g SBLH + 272g CM and T4: natural pasture hay *ad libitum*+ 754g SBLH + 181g CM; SBLH: sweet blue lupin haulm; CM: concentrate mixture; DMI: dry matter intake; OM: organic matter; CP: crude protein; NDF: neutral detergent fiber; ADF: acid detergent fiber; ADL: acid detergent lignin; LBW: live body weight; SEM: standard error of mean; SL: significance level; ns non-significant; * significant; ** highly significant.

Table 3: Apparent nutrient digestibility of Washera lambs fed natural pasture hay as basal diet and supplemented with different levels of sweet lupin haulm and concentrate mixture

Digestibility (%)	Treatments				SEM	SL
	T1	T2	T3	T4		
DM	73.2	74.7	73.9	76.6	0.02	ns
CP	74.7^{a}	74.0^{a}	70.2^{ab}	63.2^{b}	0.03	*
NDF	64.0	71.3	66.5	70.9	0.03	ns
ADF	65.0	71.4	66.8	71.9	0.03	ns
OM	74.3	76	75.7	78.3	0.02	ns

Means within a row with different superscripts are statistically significantly different; T1: Natural pasture hay *ad libitum* + 453g CM; T2: natural pasture hay *ad libitum* + 251g SBLH + 362g CM; T3: natural pasture hay *ad libitum* +503g SBLH + 272g CM; T4: natural pasture hay *ad libitum* + 754g SBLH + 181g CM; SBLH: sweet blue lupin haulm; CM: concentrate mixture; DM: dry matter; OM: organic matter; CP: crude protein; NDF: neutral detergent fiber; ADF: acid detergent fiber; SEM: standard error of mean; SL; significance level; ns is non-significant, * significant

Carcass characteristics:

Increasing the substitution level of CM by SBLH up to 40% in the diet of Washera lambs did not show a difference in the dressing percentage and carcass yield ($P > 0.05$) compared with CM supplemented groups (Tables 5 and 6). However, among all the treatment groups animals supplemented with 754 g/day SBLH showed significantly lower ($P < 0.05$) slaughter weight, hot carcass yield, pelvic and total main carcass component. The total main carcass (TMC) component follows the same trend with hot carcass in that as the level of SBLH increased the total carcass component decreased. The higher weight of kidney fat in medium and low level of SBLH with slightly medium to higher CM might be due to higher digestible OM and CP intake and higher OM and CP digestibility, which promoted better internal fat deposition in different organs. Moreover, the size of kidney, kidney fat and total edible offal were significantly ($p < 0.05$) affected by supplementation (Table 5). In this study, there was no significant difference ($p>0.05$) among treatments in heart, liver, tongue, pelvic fat and testicles size. Though, most of carcass and non-carcass parameters largely remained similar among carcass parameters largely remained similar among

Table 4: Body weight change and feed conversion efficiency of Washera lambs fed natural pasture hay as basal diet and supplemented with different levels of sweet lupin haulm and concentrate mixture

Measurements	Treatments				SEM	SL
	T1	T2	T3	T4		
Initial body weight(kg)	24.7	24.4	24.7	24.5	0.57	ns
Final body weight(kg)	32.5[ab]	32.3[ab]	32.7[a]	30.4[b]	0.71	*
ADG (g/day)	85.7[a]	86.3[a]	87.4[a]	68.7[b]	4.9	*
FCE (%)	9.8[a]	8.5[ab]	7.6[b]	5.6[c]	0.49	**

Means within a row with different superscripts are statistically significantly different; T1: Natural pasture hay *ad libitum* + 453g CM; T2: natural pasture hay *ad libitum* + 251g SBLH + 362g CM; T3: natural pasture hay *ad libitum* +503g SBLH + 272g CM; T4: natural pasture hay *ad libitum* + 754g SBLH + 181g CM; SBLH: sweet blue lupin haulm; CM: concentrate mixture; ADG: average daily gain; FEC: feed conversion efficiency; SEM: standard error of mean; SL; significance level; ns is non-significant, * significant; ** highly significant.

Table 5: Carcass characteristics of Washera lambs fed on natural pasture hay as basal diet and supplemented with different levels of sweet lupin haulm and concentrate mixture

Measurements	Treatments				Mean	SEM	SL
	T1	T2	T3	T4			
Slaughter weight (kg)	31.1[a]	30.6[a]	31.1[a]	29.2[b]	30.5	0.7	*
Empty body weight (kg)	17.5[ab]	17.6[a]	17.4[a]	16.0[b]	17.1	0.6	*
Hot carcass weight (kg)	15.6[a]	15.5[a]	15.2[a]	13.9[b]	15.1	0.6	*
Dressing percentage (%)	50.0[a]	50.6[a]	49.1[ab]	47.6[b]	49.3	1.1	*
Fore quarters (g)	3012.3	3131.8	3095.2	2867.3	3026.6	95.6	ns
Neck region(g)	1533.7	1452.4	1450.9	1380.5	1454.4	79.4	ns
Sternum brisket(g)	818.8	814.9	797.0	699.0	782.7	47.5	ns
Thoracic lumbar(g)	846.3	898.7	845.9	795.1	846.5	38.2	ns
Rib-eye muscle(g)	1032.1	1223.4	965.0	943.4	1041.0	120.2	ns
Abdominal muscle(g)	705.4	707.7	727.2	634.3	693.7	33.6	ns
Hind quarters(g)	3255.0	3299.9	3341.6	3128.2	3256.2	138.3	ns
Pelvic (rump) (g)	1384.8[a]	1411.4[a]	1286.6[ab]	1146.3[b]	1307.3	70.9	*
Tail fat weight(g)	1534.2	1527.8	1639.9	1354.6	1514.1	142.0	ns
Ribs(g)	1501.2	1372.4	1472.2	1315.5	1415.3	65.1	ns
TMC component (kg)	15.6[ab]	15.8[a]	15.6[ab]	14.3[b]	15.3	0.5	*

Means within a row with different superscripts are statistically significantly different; T1: Natural pasture hay *ad libitum* + 453g CM; T2: natural pasture hay *ad libitum* + 251g SBLH + 362g CM; T3: natural pasture hay *ad libitum* +503g SBLH + 272g CM; T4: natural pasture hay *ad libitum* + 754gSBLH + 181g CM; SBLH: sweet blue lupin haulm; CM: concentrate mixture; TMC: total main carcass; SEM: standard error of mean; SL; significance level; ns is non-significant, * significant.

Table 6: Non edible offal components of Washera lambs fed natural pasture hay as basal diet and supplemented with sweet blue lupin haulm and concentrate mixture

Variables	Treatments				SEM	SL
	T1	T2	T3	T4		
Head without tongue (g)	1590.2	1737.1	1668.9	1521.2	88.3	ns
Skin (g)	3207.9	3156.1	2997.9	2831.6	158.9	ns
Feet (g)	802.8	810.5	820.0	749.0	25.4	ns
Lung with trachea (g)	475.5	464.9	462.1	481.2	39.3	ns
Spleen (g)	43.8	46.5	46.5	43.9	3.0	ns
Gall bladder + bile (g)	28.6[a]	27.8[ab]	14.3[c]	16.6[c]	4.0	**
Stomach (g)	41.2[b]	50.5[ab]	52.9[a]	47.3[ab]	3.8	*
Bladder (g)	35.1	54.0	55.2	37.3	7.5	ns
Gut content (kg)	3.9[b]	3.3[b]	4.1[b]	4.6[a]	0.3	*
Total non-edible carcass component (kg)	6.2	6.5	6.2	5.8	0.2	ns

Means within a row with different superscripts are statistically significantly different; T1: Natural pasture hay *ad libitum* + 453g CM; T2: natural pasture hay *ad libitum* + 251g SBLH + 362g CM; T3: natural pasture hay *ad libitum* + 503g SBLH + 272g CM; T4: natural pasture hay *ad libitum* + 754g SBLH + 181g CM; SBLH: sweet blue lupin haulm; CM: concentrate mixture; TMC: total main carcass; SEM: standard error of mean; SL; significance level; ns is non-significant, * significant: ** highly significant

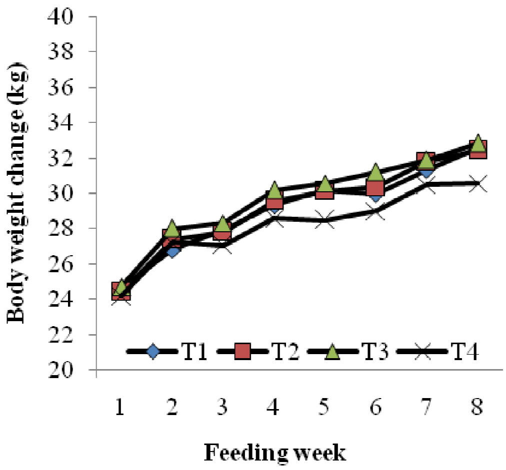

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Fig. 1: Trends in body weight change of Washera lambs fed grass hay supplemented with different levels of sweet lupin haulm and concentrate mix

testicles, gall bladder and stomach decreased ($P < 0.05$) at higher levels of SBLH inclusion.

DISCUSSION

The CP content of grass hay in the current study was below the minimum level (7%) required for normal rumen microbial growth and fermentation (Van Soest, 1994). The low CP and high fiber (NDF and ADF) content of grass hay could be attributed to the stage of maturity of the pasture from which the hay was prepared. Advance in maturity of plants is usually associated with low CP and high cell wall content (McDonald et al., 2002). On the other hand, the CP content of SBLH in this study is higher than Faba bean haulm (5.8%) reported by Seyoum et al. (2007). On the other hand, the CP content of SBLH in this study is lower than ground nut hay (11.6%) (Tsafiyo et al., 2022) in Assosa, Ethiopia. The variation might be associated with variation in plant species, climatic and soil condition. The NDF content of forages is a major factor affecting feed intake which in turn is believed to be one of the most essential factors influencing animal performance (McDonald et al., 2002). The fiber fractions (NDF and ADF) contents of natural pasture hay in this study were higher than the report of Denekew et al. (2005) and Zewdu et al. (2010) in similar areas. The variation might be associated with difference in management systems and harvesting time. The NDF content of grass hay was lower than hay used by Yeheyis et al. (2012) (794.6 g/kg DM). The ADL contents of hay used in this study were higher than hay used by Yeheyis et al. (2012) who reported 89 g/kg DM of ADL, respectively.

Improvement in intake through supplementation of SBLH might be associated with the lower alkaloid content of the forage in sweet blue lupin varieties (Yeheyis et al., 2012). In addition, enhancement in intake might be associated with dietary protein supplementation which may be due to an increase in N supply to the rumen microorganisms (Van Soest, 1994). This could lead to an increase in microbial population and efficiency, thereby facilitating the rate of breakdown of the digesta, which eventually leads to increment in feed intake (Gebregiorgis et al., 2012). Moreover, the observed improvement in DM and nutrient intake when the proportion of SBLH increased in the current study might be due to an increased availability of nitrogen (N) and readily degradable OM or energy in the rumen, which in turn facilitates microbial growth and fiber digestion. The combined effect of improved ruminal environment for microbes and lowered physical limitations of intake contributed to the linear increase in the intake of total DM and nutrients by the sheep (Mengesha et al., 2017).

The relatively better CP digestibility among the three supplementation levels (0, 362 and 503 g/day) of SBLH indicate the ruminal environment has reached the right balance of nitrogen and energy for optimal microbial growth and fiber digestion (Kumara et al., 2009). Supplementation with leguminous crop residues contributes fermentable energy to the rumen in the form of available cellulose and hemicelluloses, which stimulates fiber digestion (Silva & Ørskov, 1988). Moreover, at equal digestibility, legumes contain less cell wall (hence more cellular contents) and are consumed in quantities about 20 percent greater than grasses. Another difference between legumes and grasses is that in the former lignification is restricted to the vascular bundles, whereas in grasses the lignin is more widely distributed and has a greater inhibitory effect on rate of digestion (McDonald et al., 2010).

In the present study, all experimental sheep supplemented with different levels of SBLH and CM gained better weight, indicating that supplementation to natural pasture hay diets would enable yearling Washera lambs to get energy and nutrients above their maintenance requirements. The maximum average daily weight gain obtained from the current feeding trial (87.36 g/day) appears to be higher than the findings of Gebru et al. (2015) and Ermias et al. (2013) who reported 16.4-25.3 and 34.1–63.7 g/day for the same sheep breed (Washera) and 55.5 g/day for Arsi-Bale sheep, respectively. Moreover, the ADG in the present study is higher than Ngwa and Tawah, (2002) who reported 48.93 g/day for Kirdi sheep fed on rice straw and supplemented with 300 g of groundnut haulm in Cote D'Ivoire. The variation might be due to the difference in sheep breed and type of feed used in the experiment. The daily weight gain results of this study are comparable with previous trials (87.2-89.1 g/day) using sweet blue lupin grain and concentrate mix as reported for the same sheep breed (Yeheyis et al., 2012; Ephrem et al., 2015). The significant decrease in FCE (weight gain to DM intake ratio) with the increased level of SBLH inclusion (60%) showed less advantage, as it increases the cost of feed per unit of weight gain.

In this study the carcass characteristics, i.e., hot carcass weight and dressing percentage on slaughter weight basis is different from the report of Abebe & Tamir (2016) in that supplemented groups showed higher value than control groups. Conversely, in this study there was no difference between low and medium level of SBLH with that of high and medium level of concentrate supplementation in hot carcass and dressing percentage. The variation might be due to the difference in ingredients and level of concentrates used in this experiment and that of others. In contrast to the present study, Mengesha et al. (2017) reported dressing percentage and hot carcass weight become higher at increasing level of tagasaste (*Chamaecytisus palmensis*) supplementation. This might be due to the difference in sheep breed used and also different nature of treatment feeds used. The proportions of important visceral organs such as liver and lung remained unchanged, indicating absence of toxicity effects that may induce abnormalities in these organs. Kirton et al., (1992) reported that live weight and nutritional status of the animals can affect the production efficiency of carcass offals.

In conclusion, the results in this study depicted that substitution of CM with 20% and 40% levels of SBLH supplementation considerably enhanced nutrient intake, digestibility, live weight gain and carcass parameters of Washera lambs. Carcass parameters (slaughter weight, empty body weight, hot carcass weight and dressing percentage) were slightly lower for lambs supplemented with higher inclusion of SBLH while, those supplemented with CM and up to 40% SBLH did not show a difference. Therefore, it was concluded that supplementation of medium level of concentrate mix (272 to 362 g/head/day) with either 20% or 40% SBLH in natural pasture hay based-diet can serve as locally available replacement to expensive concentrate feeds for Washera lambs. Thus, based on relatively good biological performance and the need for less external input 40% SBLH with 60% CM is recommended as an optimum supplement feed for Washera lambs for smallholder farmers in Ethiopia. However, all supplements used in this study induced favorable ADG and therefore can be employed in feeding systems depending on their availability and relative cost.

ACKNOWLEDGEMENTS

The authors would like to thank Amhara Region Agricultural Research Institute (ARARI) for the financial support and staff of Andassa Livestock Research Center for their technical support. Our special thank also go to Mr. Alemu Tarekegn for his technical support during the carcass evaluation work.

COMPETING INTERESTS

The authors have declared that they have no competing interest.

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