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Performances of Arsi-Bale Lambs Fed Diets Based on Sugarcane Tops Silage and Hay as a Partial Substitute for Natural Pasture Hay

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በዚህ ጥናት ከሸንኮራ አገዳ ጫፍ የተዘጋጀ ድርቆሽና ገፈራ (ሳይሌጅ) ከተፈጥሮ የሣር ድርቆሽ ጋር ያለው አንጻራዊ የመኖ ጠቃሜታ በታዳጊ የሥጋ በጎች ላይ ተገምግሟል፡፡ ከሸንኮራ አገዳ ጫፍ፤ ከሞላሰስና ዩሪያ ውህድ የተዘጋጀን ገፈራ ወይም ድርቆሽ እንደአማራጭ አሳራማ መኖ በመጠቀምና የተፈጥሮ ሣር ድርቆሽን በከፊል (0፣33 እና 67 ፐ) በመተካትና ለሶስት ወራት ያህል በጎችን በመመገብ በመኖ ተበይነት፤ በበጎች እድገት፤ በሥጋ ምርትና ኢኮኖሚያዊ ጠቃሜታ ላይ መረጃዎች ተሰብስቧል፡፡ የጥናቱም ውጤት እንደምያሳየው አጠቃላይ የደረቅ መኖ ተበይነት ደረጃ ከሸንኮራ አገዳ ጫፍ ሳይሌጅ መጠን መጨመር ጋር ተያይዞ ቀንሷዋል፡፡ይሁን እንጇ የመኖዎች መለያየት በበጎች እድገትና የሥጋ ምርት ላይ እምብዛም ልዩነት አላሳየም፡፡ በተጨማሪም አብላጫውን (67በመቶ) የሸንኮራ አገዳ ጫፍ ድርቆሽ ወይም ገፈራ ያለውን መኖ የተመገቡ በጎች የተፈጥሮ ሣር ብቻ የያዘ መኖ ከተመገቡት በጎች የበለጠ አዋጪ (አትራፊ) ሆኗል፡፡ በመሆኑም በጥሩ ሁኔታ የተዘጋጀ የሸንኮራ አገዳ ጫፍ ገፈራ ወይም ድርቆሽ የተፈጥሮ ሣር ድርቆሽን በመተካት ለሥጋ እንስሳት ጠቃሚ እንደሆነ ጥናቱ ያሳያል፡፡

Abstract

This study was conducted to evaluate nutrient intake, growth performance, carcass characteristics and economic performances of yearling Arsi-Bale lambs fed diets based either sugarcane tops (SCT) silage or hay replacing natural pasture hay as a roughage source. The treatments were: natural pastures hay (NPH) without SCT (T1, control); substituting 33 and 67% NPH with either SCT silage (T2, T3) or SCT hay (T4, T5), on dry matter (DM) basis, respectively. Roughages were fed ad libitum along with 350 g/head/day concentrate mix. Thirty yearling Arsi-Bale lambs (Initial body weight, 19.36±0.27 kg) were allotted to the treatments in randomized complete block design. The feeding trial lasted for 90 days followed by slaughter for carcass evaluation. Dry matter intake was lower ($P<0.05$) for lambs on the higher silage based diet, but not affected ($P>0.05$) by the level of SCT hay. Lambs fed on a diet containing higher SCT hay had the lowest ($P<0.0001$) crude protein (CP) intake, while the intake of neutral detergent fiber (NDF) and acid detergent fiber (ADF) were lower ($P<0.05$) on higher silage diet, which associated with lower DM intake. Treatments did not vary ($P>0.05$) in growth performances, feed efficiency (FE) and carcass characteristics of the lambs. The average final body weight, body weight change, average daily gain (ADG) and feed efficiency (FE) were: 27.21 kg, 7.85 kg, 87.22 g and 0.110 (g gain/g DM intake), respectively. Higher net income (113.08 Birr/lamb) and profit margin (0.47 Birr/lamb) were fetched by lambs fed on the silage based diet, followed by the group fed SCT hay and control diet. In conclusion, SCT silage or hay can replace up to 67% of natural pasture hay for yearling Arsi-Bale lambs at an economic advantage.

Keywords: Sugarcane top, sheep, growth, carcass, cost-benefit

Introduction

Nowadays, investment in the sugar industry has favored the production and availability of sugarcane byproducts (e.g., molasses, bagasse and sugarcane tops) in Ethiopia, making them valuable livestock feed (Adugna *et al*., 2012; Adugna and Makkar, 2018). The inclusion of sugarcane byproducts in the diet of ruminants provides energy and fiber, besides increasing feed supply and reducing the cost of production. They serve as alternative feed resources to others that are limited or not affordable to most livestock producers. At sugar factories, the byproducts are available in bulk during sugarcane harvesting (between October and June), which coincides with the period of feed shortage. Lack of quality roughage is a notable challenge to livestock production in such areas, particularly during the dry season and at drought occurrence. Also, the small-scale sugarcane farms prevailing in different parts of the country (Esayas *et al*., 2016) contribute to the production of green SCT and leaves. However, quite a large part of these byproducts are underutilized being dumped or removed by burning. When properly collected, processed, conserved and improved, sugarcane byproducts can alleviate feed deficit facing small-scale livestock farms.

Sugarcane tops represent 15-25% of the aerial plant biomass (Suttie, 2000), containing immature stems, leaves and sheaths, and are potential forages for ruminants (Naseeven, 1988). The nutritional quality of sugarcane tops has been documented, which varied with sugarcane cultivars and the stage of harvesting (Sharma *et al*., 2012). It is rich in water-soluble carbohydrates (155g/kg DM, Khanal *et al*., 1995; 82.5g/kg DM, Chaudhry and Naseer, 2008), as a desirable characteristic for successful ensiling. Sugarcane tops are deficient in protein, minerals and energy (Galina *et al*., 2007). Ensiling SCT with or without additives improves its fermentation and nutritive value (Alemzadeh and Noroozy, 2006; Siqueira *et al*., 2009). It is palatable to ruminants and can be fed with protein supplements. Experimental sheep fed on diets containing green SCT (Galina *et al*., 2007), its hay (Anteneh, 2014) or silage (Salinas-Chavira *et al*., 2013; Suliman *et al*., 2016) had maintained or increased their body weight.

In Ethiopia, lack of quality feed and its high market price are challenges of livestock production, while available non-conventional feeds resources such as SCT are underutilized. Besides, information on the biological and economic performance of using SCT silage or hay as an alternative roughage source to natural pasture hay for local sheep fattening is limited. This study was, therefore, hypothesized to test the feeding value of SCT silage or - hay as a substitute for natural pasture hay on the major productive and economic performances of yearling Arsi-Bale sheep.

Materials and Methods

This study was carried out at the Sheep Research Unit of the Debre Zeit Agricultural Research Center, Ethiopia. The center is located at 45 km Southeast of Addis Ababa (08°44'N latitude, 38°58'E longitude; altitude of 1900 meters above sea level). It is known for bimodal rainfall distribution (June-September and March-May), with an average annual rainfall of 814 mm and minimum and maximum temperature of 10.9 and 28.3°C, respectively.

Feed preparation

Burnt SCT (variety N-14) of sugarcane grown on heavy black soil (*Vertisols*) and at the first stage of cutting after planting was collected postharvest from Wonji-Shoa sugarcane field and transported to the Research Center. Part of SCT was immediately chopped into 2-3 cm using a forage chopper and ensiled by adding 1% urea and 4% molasses solution as a percent of roughage used (on DM basis), For this, 5 ground Pits each with a dimension of 1.20 m length, 1.20 m width and 1.50 m depth and a capacity of about 500-600 kg fresh roughage was prepared. The chopped forages were homogenized manually with the additive, filled and well-compacted batch by batch using casual workforce (ensiling 10kg/batch forage) in the pits lined with polyethylene sheet, which finally sealed and left to ferment under the anaerobic condition for 45 days. The pits accommodated the total amount of SCT silage required for the feeding period. On the other hand, an adequate amount of chopped burnt SCT (2-5 cm long) was sun-dried (to 85% DM) for three days and stored under a shed. Concentrate feed (90.7% DM) was prepared from 14.6% ground maize, 34.8% wheat bran, 49.6% *noug* seed (*Guizotia abyssinica*) cake and 1% common salt (on DM basis). Moreover, natural pasture grown on wetlands of Ethiopian highland and dominated by grass species (*Andropogon abyssinicus, Pennisetum and Cyperus/Sedge)* (Seyoum and Fekede, 2008) was harvested at a half month past full heading stage and sun-dried.

Animals, feeding management, treatments and design

Thirty yearling intact Arsi-Bale lambs were purchased from local markets. The lambs were of highland origin, reared on grazing and in similar dentition (with unbroken paired incisors). All animals were ear-tagged and quarantined for three weeks, during which they were vaccinated against viral diseases (sheep pox, pasteurellosis and anthrax) and treated with a broad-spectrum antiparasitic agent (Ivermectin) against internal and external parasites. The animals were adapted to the test diets for two weeks and weighed after overnight fasting for two consecutive days. The average body weight was used to categorize animals into six blocks. Animals within each block were allotted to one of the five dietary treatments (6 lambs/treatment) in a randomized complete block design. Experimental lambs were managed in individual pens (0.70 m × 1.70 m) with concrete floor, a feeding trough and a watering bucket. The pens were disinfected before moving animals in and then cleaned daily.

Table 1 indicates the physical and chemical compositions of feed ingredients. Sugarcane tops silage or hay replaced natural pasture hay on a dry matter (DM) basis at feeding. Silage was wilted overnight before offered to the lambs the next morning. Besides, each animal was supplemented with a concentrate mix (350 g/day; 90.71% DM).

Table 1. Physical and chemical compositions of feedstuffs used in the feeding trial

	Natural pasture hay	Burnt SCT silage	Burnt SCT hay	Concentrate (g/day)*
Physical composition (as %DM, except for DM):				
T_1 (control)	100	-	-	350
T_2	67	33	-	350
T_3	33	67	-	350
T_4	67	-	33	350
T_5	33	-	67	350
Nutrient composition, % DM:				
Dry matter (%)	86.97	34.23	87.73	90.71
Crude protein	4.56	4.75	3.50	20.15
Ash	9.44	10.90	14.43	6.58
Neutral detergent fiber	69.02	65.55	71.71	42.38
Acid detergent fiber	46.17	38.36	42.07	17.62
Acid detergent lignin	9.53	8.25	7.30	5.86

* = as fed basis (DM, 90.71%); SCT= sugarcane tops; T = treatment

Intake and growth measurements

Feed intake and growth trial lasted for 90 days of data collection. The roughages were fed *ad libtum* allowing 15% refusal daily, while concentrate was fed twice daily at 8:00 am and 2:00 pm. Tap water was provided for all animals free of choice. Daily feed offered and refusal was measured and recorded for each animal to determine nutrient intake by difference. Samples of roughage and concentrate offered and refusals were taken daily and sub-sampled biweekly for DM determination. All animals were weighed every 15 days after overnight fasting. The average daily gain (ADG) of each lamb was estimated by regressing the difference between two successive bodyweights over days elapsed. FE was determined by dividing ADG (g) by daily feed DM intake (g).

Carcass measurements

After the completion of the feeding trial, the lambs were transported to ELFORA export abattoir in Debre Zeit town. The lambs were devoid of feeds for 18 h, weighed and slaughtered. After bleeding the animals, skin, heads, blood, liver, kidney, heart, lung and trachea, testis and penis, spleen, tail fat, omental fat, gut total, digesta and empty gut and internal organs were removed, weighed and recorded. Hot carcasses were weighed including the tail fat and split along the vertebral column into the left and right sides. From all lambs, adequate samples of *longissimus dorsi* muscle *(*meat) of the right half carcass (5^{th}-13^{th} ribs) and immediately vacuum-packed in plastic bags and stored in a deep freezer (-20°C) until used for the subsequent laboratory works. The left sides of the carcass were chilled for 24 hrs at 4°C, deboned into lean, fat and bone components and weighed. Each component was multiplied by two (except tail fat) and expressed as a proportion of whole carcass weight or empty body weight (EBW). The digestive tract was weighed when full and empty in order to compute gut content (digesta) by difference. Empty body weight was computed by deducing the weight of the gut content from the slaughter weight. The non-carcass parameters were assayed as a percent of EBW, except for digesta that was estimated as a percent of SBW. Chilling loss was calculated as the percentage of the difference between hot carcass weight (HCW) and cold carcass weight (CCW) divided by HCW. Dressing percentage was calculated as the proportion of hot and cold carcass weight to slaughter weight or EBW: HCW (CCW)/SBW*100 and HCW (CCW)/ EBW*100.

Cost-benefit analysis

The partial budget analysis was used to evaluate the relative economic importance of dietary treatments using the procedures of Upton (1979). It measures profit or losses, where net income (NI) is the difference between total returns (TR) and total variable costs (TVC): NI = TR-TVC. The change in net income (ΔNI) was the difference between the change in total return (ΔTR) and the change in total variable cost (ΔTVC), i.e., ΔNR = ΔTR - ΔTVC. While, the marginal rate of return (MRR) measures the increase in net income (ΔNI) associated with each extra unit of cost (ΔTVC), i.e., MRR = (Δ NI/ ΔTVC). The economic benefit of production was estimated considering the costs of major inputs (feeds and labour) and the prevailing (end of the main fasting season of Ethiopian Orthodox Christian) market price of finishing lambs as estimated by three experienced local sheep traders.

Chemical analysis of samples

Feed samples were dried in forced air oven at 60°C for 72 hours to a constant weight and ground to a 1.0 mm size using a Wiley mill and stored in plastic bags. Dry matter, CP (N *6.25), ash, EE, calcium (Ca) and phosphorus (P) contents were determined according to AOAC (1990), while neutral detergent fiber (NDF), acid detergent fiber (ADF) and acid detergent lignin (ADL) contents were analyzed according to Van Soest and Robertson (1985).

Statistical model and data analysis

After testing for data normality, experimental data were subjected to analysis of variance using the General Linear Model procedure of the SAS program (SAS, 2004). Mean separation was done using Tukey test at 5% probability. The statistical model was: $Yij = \mu + Ti + Bj + \varepsilon ij$. Where: Yij = Experimental observation; μ = Grand mean of treatments; Ti = Effect of treatment; Bj = Effect of block; εij = Experimental error.

Results and Discussion

Nutrient intake

Intake of DM, CP and fiber fractions significantly (*P*<0.05) reduced by the inclusion of SCT silage (Table 2). In T_2, the roughage and total DM intakes were depressed (*P*< 0.05) by about 26.4 and 16.5%, respectively, over that of the control diet (T_1). The lower nutrient consumption at the higher silage level might be attributed to its high moisture content (65.8%) that might have increased rumen fill and reduced DM intake. In agreement with the present result, Salinas-Chavira *et al* (2013) observed a decrease in DM intake of Pelibuey sheep fed on diets containing 5-10% SCT silage as a substitute for sorghum stover. Also, DM intake of Merino sheep was depressed as the maize silage portion of the ration increased from 20 to 70% (Beukes, 2013). It was reported that the DM intake of dairy cattle was reduced at higher silage allowance due to its higher content of acetic acid (Daniel *et al.*, 2018) or change in odor, taste and texture of the silage (Rodríguez *et al.*, 2015). Moreover, depression in the intake of silage based diets was prominent in sheep than in cattle, especially with partially fermented silages containing high ammonia and butyrate (>1%) (Forbes, 2007 as cited in Beukes, 2013). In this study, since the intake of fiber fractions decreased at the higher silage inclusions, the negative role of low fiber intake in reducing total DM intake might be attributed to its effect on lowering digestibility. In the present study, replacing native pasture hay partially with SCT hay did not affect (*P*>0.05) intake of DM, ash, NDF and ADF in lambs, while intake of CP and ADL were reduced (*P*<0.001) at higher inclusion level. The non-significant difference among treatments in SCT hay DM intake agreed with the research reports for Washera sheep supplemented with SCT hay (Anteneh, 2014) and goats fed on sugarcane and Guinea grass based diets (Bien, 1999). The lowest dietary CP intake at higher substitution rate (67%) of SCT hay could be attributed to its low CP content and the reduction in grass hay consumption. The total DM intake was peaked up to day 60th and 75th of the feeding period (Figure 1).

Table 2. Mean nutrient intake (g/day) of Arsi-Bale lambs fed diets based on SCT silage and/or /hay as a partial substitute for natural pasture hay

Variable	Treatment (T)					SEM	*P*-value
	T_1	T_2	T_3	T_4	T_5		
rDM	526^{a}	505^{a}	387^{b}	526^{a}	456^{ab}	34.6	0.0404
tDM	843^{a}	821^{a}	704^{b}	842^{a}	774^{ab}	34.8	0.0427
rCP	24^{a}	23^{ab}	18^{b}	24^{ab}	10^{c}	1.5	<.0001
tCP	88^{a}	87^{ab}	82^{b}	88^{ab}	74^{c}	1.6	<.0001
rAsh	49	51	41	50	48	3. 6	0.2977
tAsh	70	72	62	71	69	3.6	0.3047
rNDF	358^{a}	332^{ab}	251^{b}	376^{a}	326^{ab}	23.8	0.0121
tNDF	493^{a}	466^{ab}	386^{b}	509^{a}	460^{ab}	23.9	0.0125
rADF	243^{a}	203^{ab}	143^{b}	226^{a}	185^{ab}	15.5	0.0012
tADF	299^{a}	259^{ab}	199^{b}	282^{a}	241^{ab}	15.5	0.0013
rADL	48^{a}	43^{ab}	30^{b}	43^{ab}	31^{b}	3.2	0.0019
tADL	67^{a}	61^{ab}	49^{b}	62^{ab}	50^{b}	3.2	0.0020

[a,b,c]Means with different superscript letters in the same row differ significantly (P<0.05); T_1(control) = 100% Natural pasture hay ad libtum+ 350 g/day concentrate; T_2 = (67% Natural pasture hay + 33% SCT silage) ad libtum + 350 g/day concentrate; T_3 = (33% Natural pasture hay + 67% SCT silage) ad libtum + 350 g/day concentrate; T_4 = (67% Natural pasture hay + 33% SCT hay) ad libtum + 350 g/day concentrate; T_5 = (33% Natural pasture hay + 67% SCT hay) ad libtum + 350 g/day concentrate; t = total; r = roughage; DM = dry matter; CP= crude protein; NDF = neutral detergent fiber; ADF = acid detergent fiber; ADL = acid detergent lignin; SEM = standard error of mean.

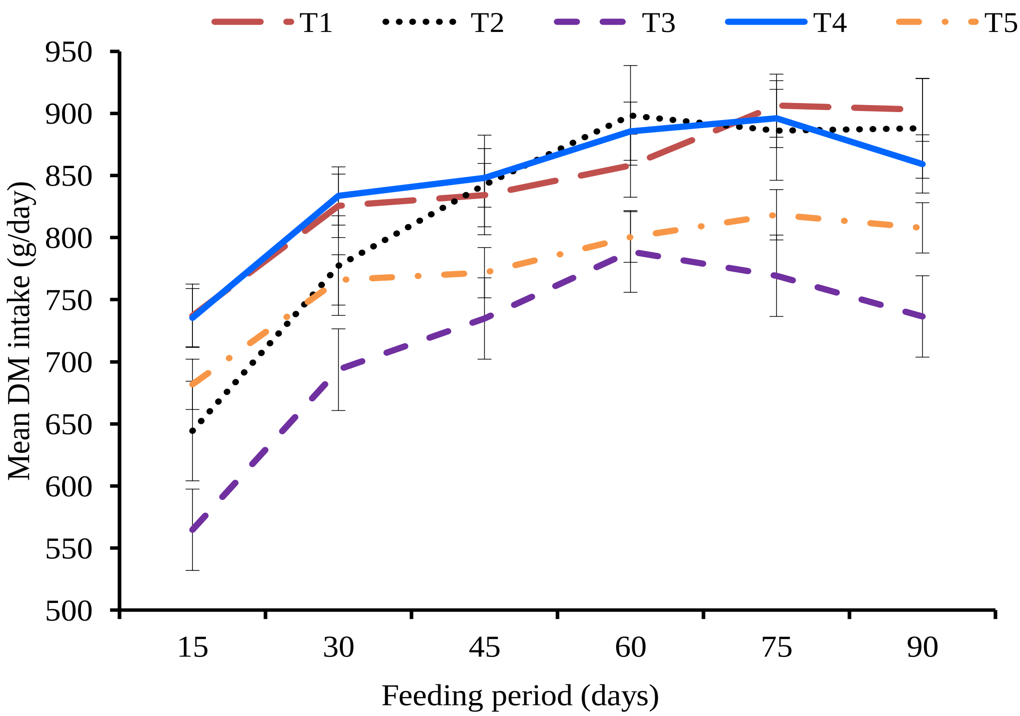

Figure 1. The trend of dry matter intake for experimental lambs (error bars, SE)

Growth performances

Treatments did not differ (*P*>0.05) in the growth performances of lambs (Table 3). The overall average final body weight, body weight change, ADG and FE of the treatments were 27.21 kg, 7.85 kg, 87 g and 0.11, respectively. The trends of average body weight of lambs were increasing with advance in the feeding period. However, compared to others, lambs in T3 grew relatively at a slow rate, particularly after 60 days of feeding (figure 2). The average daily gain and FE of lambs in the present study were agreed with performances of sheep fed on diets based green SCT silage (Aguirre *et al*., 2010; Salinas-Chavira *et al.*, 2013) and intact green SCT (Galina *et al*., 2007). Similarly, Julião *et al* (2016) reported the partial (33-66%) substitution of whole sugarcane by SCT on high-concentrate diets for feedlot Nellore bulls did not affect their growth performances. However, the ADG of lambs in the present study was higher than 45-75 g reported for Washera sheep fed chopped SCT hay (120-360 g/day) and natural pasture hay (Anteneh, 2014), but was lower than Pelibuey sheep fed SCT silage based diet (Salinas-Chavira *et al.,* 2013). However, the differences could also be related to the variation in the growth potential of the breeds. In the present study, the non-significant difference (P>0.05) among the treatments in growth performances could be related to the similarity in the nutrient supply of the diets. Remarkably, lambs with low DM intake (T_3) had equivalent growth performances to the other treatment groups probably indicating the higher energy value of SCT silage over SCT hay or natural pasture hay used in this study. In agreement, Salinas-Chavira *et al* (2013) observed no difference in ADG of Pelibuey sheep fed SCT silage replacing sorghum stover, although DM intake was decreased with silage inclusion.

Table 3. Growth and feed efficiency of Arsi-Bale lambs fed diets based on SCT silage/hay as a partial substitute for natural pasture hay

Parameter	Treatment (T)					SEM	*P*-value
	T_1	T_2	T_3	T_4	T_5		
Initial BW (kg)	19.40	19.38	19.33	19.42	19.27	0.27	0.9959
Final BW (kg)	27.63	27.42	26.58	27.13	27.29	0.78	0.9029
BW change (kg)	8.23	8.04	7.25	7.71	8.02	0.64	0.8381
ADG (g)	91	89	81	86	89	7	0.8381
FE (g gain/g DMI)	0.110	0.110	0.113	0.102	0.115	0.009	0.8890

Means with different superscript letters in the same row differ significantly (P<0.05); T_1(control) = 100% Natural pasture hay ad libtum + 350 g/day concentrate; T_2 = (67% Natural pasture hay + 33% SCT silage) ad libtum + 350 g/day concentrate; T_3 = (33% Natural pasture hay + 67% SCT silage) ad libtum + 350 g/day concentrate; T_4 = (67% Natural pasture hay + 33% SCT hay) ad libtum + 350 g/day concentrate; T_5 = (33% Natural pasture hay + 67% SCT hay) ad libtum + 350 g/day concentrate; BW = Body weight; ADG = average daily gain; FE = feed efficiency; DMI = Dry matter intake; SEM = standard error of mean; vs = versus

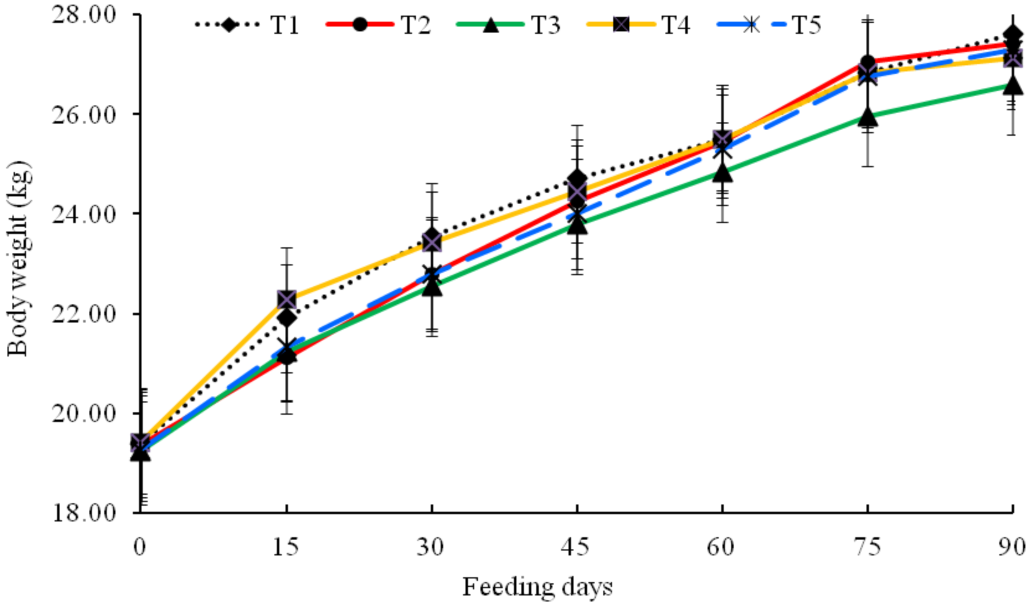

Figure 2. Trend of lambs' body weight change as affected by the experimental diets (error bars, SE)

Carcass and non-carcass traits

The carcass characteristics of experimental animals were not affected (*P*<0.05) by the substitution of natural pasture hay with SCT silage or hay, where the overall average for SBW, EBW, HCW, CCW, chilling loss, DP (%SBW), lean meat, fat and bone were 26.08 kg, 21.30 kg, 11.26 kg, 10.94 kg, 2.88%, 43.27%, 5.91 kg, 1.58 kg and 2.65 kg, respectively (Table 4). The absence of variation among the treatments in the magnitude of carcass traits might have indicated the similarity in the nutritional value of the experimental diets. The relatively higher dressing percentages of lambs when expressed on empty body weight (EBW) than on slaughter body weights were due to the removal of digesta that accounted for 18.2% of SBW. It is noted that chilling loss had minor effect in lowering the dressing percentage (DP). Higher SBW, HCW, CCW and DP were reported for Washera sheep supplemented with sun-dried chopped SCT than the group not supplemented (Anteneh, 2014). However, Suliman *et al* (2013) observed no difference in the proportion of lean meat, fat, bone and DP among Saidi rams fed SCT silage and berseem hay with concentrate supplementation. The values of SBW, HCW, CCW, DP observed in the current study were close to that reported for feedlot Arsi-Bale lambs (Abebe *et al.*, 2010; Getahun, 2015) and pure Hararghe and Black Head Ogaden sheep, but was lower than the crossbred (50% local x 50% Dorper) (Tsegay *et al.*, 2013). Moreover, Girma *et al* (2010) reported lower DP (36.2-38.5, %SBW) than the present DP for yearling Arsi-Bale lambs raised on pasture and in a feedlot.

Table 4. Carcass characteristics of Arsi-Bale lambs fed diets based on SCT silage and/or hay as a partial substitute for natural pasture hay

Parameter	Treatment (T)					SEM	*P*-value
	T_1	T_2	T_3	T_4	T_5		
SBW, kg	25.58	26.00	25.83	25.83	27.17	0.83	0.6958
EBW, kg	21.22	20.95	21.64	20.87	21.80	0.59	0.7455
HCW, kg	11.42	11.00	11.25	11.17	11.48	0.28	0.7633
CCW, kg	11.18	10.77	10.95	10.77	11.02	0.32	0.8921
ChLoss (%)	2.06	2.12	2.92	3.34	3.97	1.16	0.7357
*h*DP (%SBW)	44.78	42.37	43.56	43.23	42.42	0.99	0.4272
*h*DP (%EBW)	53.89	52.49	51.97	53.41	52.78	0.90	0.6002
*c*DP (%SBW)	43.82	41.47	42.30	41.70	40.69	0.90	0.1814
*c*DP (%EBW)	52.76	51.38	50.46	51.55	50.65	0.87	0.3860
Lean meat (kg)	6.03	5.66	5.89	5.87	6.09	0.23	0.7300
Fat (kg)	1.72	1.71	1.47	1.59	1.42	0.20	0.7878
Bone (kg)	2.77	2.63	2.74	2.49	2.62	0.12	0.4738

Means with different superscript letters in the same row differ significantly (P<0.05); T_1(control) = 100% Natural pasture hay ad libtum + 350 g/day concentrate; T_2 = (67% Natural pasture hay + 33% SCT silage) ad libtum + 350 g/day concentrate; T_3 = (33% Natural pasture hay + 67% SCT silage) ad libtum + 350 g/day concentrate; T_4 = (67% Natural pasture hay + 33% SCT hay) ad libtum + 350 g/day concentrate; T_5 = (33% Natural pasture hay + 67% SCT hay) ad libtum + 350 g/day concentrate; SBW = slaughter body weight, HCW = hot carcass weight; CCW = cold carcass weight; ChLoss = chilling loss; EBW = empty body weight; hDP = hot dressing percentage; cDP = cold dressing percentage; SEM = standard error of mean

Except for the proportion of skin (expressed as %EBW), which was significantly (P<0.05) lower in T_1 than T_2, the other non-carcass parameters did not vary (P>0.05) among the treatments (Table 5). The grand mean of the non-carcass parameters (%EBW, except for digesta as %SBW) were: 13.90 (skin), 8.87 (head), 4.95 (blood), 1.82 (liver), 0.35 (Kidney), 0.61 (Heart), 1.47 (Lung and trachea), 2.01 (Testis and penis), 0.21 (spleen), 2.96 (tail fat), 1.01 (Omental fat), 6.77 (gut total), 1.98 (empty gut) and 18.23(digesta). The values of most non-carcass parameters observed in the present study were consistent with previous research reports for the same breed of sheep in indoor management (Abebe *et al.*, 2010; Girma *et al.*, 2010; Getahun, 2015).

Table 5. Non-carcass components of Arsi-Bale lambs fed diets based on SCT silage/hay as a partial substitute for natural pasture hay

Parameter	Treatment (T)					SEM	*P*-value
	T_1	T_2	T_3	T_4	T_5		
%EBW							
Skin	12.90^{b}	14.93^{a}	13.95^{ab}	13.44^{ab}	14.27^{ab}	0.42	0.0254
Head	9.39	9.27	9.05	8.87	7.76	0.74	0.5607
Blood	5.36	4.83	4.73	5.14	4.67	0.49	0.8313
Liver	1.88	1.80	1.74	1.87	1.79	0.06	0.4061
Kidney	0.38	0.33	0.34	0.37	0.35	0.01	0.1243
Heart	0.60	0.66	0.57	0.63	0.59	0.05	0.7332
Lung with trachea	1.49	1.49	1.49	1.43	1.46	0.06	0.9458
Testis and penis	1.93	2.05	2.15	2.15	1.78	0.12	0.1634
Spleen	0.23	0.19	0.22	0.22	0.19	0.02	0.6229
Tail fat	3.27	3.36	3.02	2.64	2.51	0.44	0.5760
Omental fat	1.06	1.02	0.99	1.14	0.84	0.16	0.7756
Gut total(kg)	6.37	7.02	6.12	6.98	7.38	0.44	0.2708
Empty gut (kg)	2.00	1.97	1.92	2.02	2.01	0.07	0.8691
Digesta (%SBW)	16.92	19.29	16.18	19.08	19.68	1.07	0.1019

$^{a-b}$Means with different superscript letters in the same row differ significantly (P<0.05); T_1(control) = 100% Natural pasture hay ad libtum + 350 g/day concentrate; T_2 = (67% Natural pasture hay + 33% SCT silage) ad libtum + 350 g/day concentrate; T_3 = (33% Natural pasture hay + 67% SCT silage) ad libtum + 350 g/day concentrate; T_4 = (67% Natural pasture hay + 33% SCT hay) ad libtum + 350 g/day concentrate; T_5 = (33% Natural pasture hay + 67% SCT hay) ad libtum + 350 g/day concentrate; SEM = standard error of mean; EBW = empty body weight

Cost-benefit analysis

The partial replacement (33 and 67 parts) of natural pasture hay with SCT silage and hay for yearling Arsi-Bale lambs had a positive effect in reducing the production cost (Table 6). The group fed on diet with a higher level of SCT silage (T_3) achieved the highest positive net income and profit margin (T_1). Compared to the control diet, feed cost was reduced by 27.8% (454.77 vs 328.57 Birr/lamb) and 24.1% (454.77 vs 345.15 Birr/lamb) in the group fed on the higher level of SCT silage and SCT hay. Feed cost accounted for about 79, 67 and 70% of total variable cost (TVC) in the control diet and at higher SCT silage or SCT hay inclusion, respectively. In other words, feed cost share of TVC was reduced by about 12% in higher silage diet and 9% in higher SCT hay diet compared to the control diet.

Although all experimental lambs biologically performed equally, the diets with a higher proportion of SCT silage (T_3) and SCT hay (T_5) had better economic benefits mainly due to the low cost of SCT and reduced consumption of costly natural pasture hay. The study revealed that the partial replacement of natural pasture hay with chopped SCT silage or hay is cost-effective and can increase income for farmers under local conditions. In line with the present results, Anteneh (2014) reported increased net income and profit margin with an increase in the level of chopped SCT hay offer for feedlot Washera sheep. Contrarily, Julião *et al* (2016) reported that the partial (33-66%) substitution of whole sugarcane by SCT for Nellore bulls neither reduced the production cost nor increased the profit margin, but had an economic benefit at total substitution rate. The present study also disclosed that the inclusion of SCT in the ruminant diet is economical and feasible for most livestock farms around sugar industries, as they collect it freely from fields or obtain it at a minimum cost from collectors.

Table 6. Economic parameters (Birr/lamb) of Arsi-Bale lambs fed diets based on SCT silage/hay as a partial substitute for natural pasture hay

	Treatment (T)				
Variable costs	T_1	T_2	T_3	T_4	T_5
Initial price of sheep	800	800	800	800	800
Hay cost	275.14	177.09	66.82	184.5	78.75
SCT purchase	0	47.43	73.77	49.41	86.94
Concentrate cost	179.63	178.52	179.21	178.78	179.46
Cost of molasses and urea	0	5.64	8.77	0	0
Silage/hay making costs	0	42.5	42.5	28.33	28.33
Labour cost for managing lambs	103.13	103.13	103.13	103.13	103.13
Medication cost	15.5	15.5	15.5	15.5	15.5
Selling price of lambs	1447.22	1388.89	1402.78	1436.11	1386.67
TR (A)	647.22	588.89	602.78	636.11	586.67
∆TR	0	58.33	44.44	11.11	60.55
TVC (B)	573.4	569.81	489.7	559.65	492.11
∆TVC	0	3.59	83.7	13.75	81.29
NI (A-B)	73.82	19.08	113.08	76.46	94.56
∆NI (∆TR-∆TVC)	0	-54.74	39.26	2.64	20.74
MRR = ∆NI/∆TVC	0	-15.25	0.47	0.19	0.26

T_1 (control) = 100% Natural pasture hay ad libtum + 350 g/day concentrate; T_2 = (67% Natural pasture hay + 33% SCT silage) ad libtum + 350 g/day concentrate; T_3 = (33% Natural pasture hay + 67% SCT silage) ad libtum + 350 g/day concentrate; T_4 = (67% Natural pasture hay + 33% SCT hay) ad libtum + 350 g/day concentrate; T_5 = (33% Natural pasture hay + 67% SCT hay) ad libtum + 350 g/day concentrate; NI= net income; TR= total return; TVC=total variable cost; MRR= marginal rate of return; ETB= Ethiopian currency (Birr); Feed cost (Birr/kg) (natural pasture hay, 5; SCT, 1.07; concentrate mix, 5.63; urea, 10; molasses, 0.86)

Conclusion

In conclusion, substitution of 67 parts of native pasture hay by SCT silage restricted DM intake of Arsi-Bale lambs, without impairing growth performances and carcass traits. Up to 67% replacement of native pasture hay by SCT silage or hay reduced production cost, increasing economic benefits. Thus, conserved SCT can partially substitute native pasture hay as a basal diet for meat sheep production.

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