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Carcass and meat quality characteristics of two hair type breed lambs fed *tef* (*Eragrostistef*) straw ensiled with effective micro-organisms and supplemented with concentrates

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The experiment was conducted with the objective of studying the carcass characteristics and meat quality of Arsi-Bale lambs (AB) and Afar lambs (Af) fed on tef straw (TS) ensiled with effective microorganisms and supplemented with concentrate. The experimental design was complete randomized block with two factors having 7 replications. Each lamb was fed on TS silage alone, or supplemented with either wheat bran Bokashi alone or mixed with noug seed cake. The results indicated that, except for chilling loss and the dressing percentages the AB were better than the Af in all the carcass characteristics that were improved by supplementation. Most of the carcass linear measurements were influenced only by diet which made the supplemented lambs performed ($p>0.05$) better ($p<0.05$) than the control. The meat physicochemical and chemical characteristics were similar for both except L* value and fat content were higher for Af. Control lambs had higher ($p<0.05$) meat pH_{24}, moisture and ash contents, and lower fat content. The eating qualities were similar ($p>0.05$) for both breeds, though better ($p<0.05$) for the supplemented. It is concluded that compared to the Af the AB can produce similar quality but better lean meat yield.

Key words: Bokashi, Tef straw silage, meat quality, morphometric carcass measurements, sensory evaluation, physicochemical characteristics.

INTRODUCTION

Ethiopia has high sheep genetic diversity that has been developed by natural selection (Galal, 1983). Meat

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production is the most important function of these animals in Ethiopia. *Washera*, *Bonga*, *Horro*, *Arsi-Bale* and *Adilo* are among Ethiopian sheep breeds that produce mutton well in good environmental conditions while Afar and Black Head *Somali* are good producers of mutton even in environment with limited feed and water (Gizaw, 2008). The demands for their meat in the country especially during religious festivals is very high (Amha, 2008).

This demand had made sheep husbandry important in pastoral, agro-pastoral and mixed farming areas as a source of cash income, food security, household meat consumption, live animal savings and manure supply (Hassen and Tesfaye, 2014; Tibbo, 2006). Furthermore, Ethiopia's commercial red meat industry, mainly of small ruminants, has made remarkable progress to date and shows considerable growth potential for the future (U.S. Embassies Abroad, 2017; AGP-LMD, 2013). As a result, the Ethiopian Government, as part of its livestock master plan, intends to transform the livestock sector and increase production and exports of meat (U.S. Embassies Abroad, 2017).

Despite the growing market demand, the chronic challenges that livestock production is facing have kept the benefit at minimal (Amha, 2008). Among the challenges, one which is aired loudly is problem of highland sheep mutton's short shelf life (darkening) (Abebe et al., 2010) that limits export to the lowland sheep only (Akililu et al., 2005). Additionally, meat from Ethiopia could not attract a high price as a result of lacking established grades and brands of Ethiopian identity in the export market. Hence, producers have no incentive to raise animals producing high-quality carcasses (Amha, 2008). There are only a few studies aimed at elucidating the causes and possible remedies for the dark cut meat problem held on export market targeted sheep breeds (BHO from lowland and Arsi-Bale from highland (Merera et al., 2015; Merera et al., 2013; Abebe et al., 2010; Merer et al., 2010) though the Afar breed was also important export sheep. These studies focus only on length of rest and feeding after transportation, assuming that transportation is the major responsible factor. Yet, as important as the transportation stress, nutrition and feeding regimes especially provision of antioxidant are reported to be causes and remedies for dark cutting meat (Ponnampalam et al., 2017). In this regard, Effective Microorganisms (EM) as biological inoculants were believed to improve nutritional quality of poor quality feed resources (Balogun et al., 2016; Samsudin et al., 2013; Yonatan et al., 2013).

EM is a mixture of aerobic and anaerobic microorganisms, specifically, lactic acid bacteria, yeast, and photosynthetic bacteria, fermenting fungi and actinomycetes that survive together synergistically and fight off pathogens and rotting microorganisms (Higa and Wididana, 1991, Talaat et al., 2015). The growth of pathogenic microorganisms is checked by the inhibiting effect of lactic acid as a result of reduced pH, while the yeast feed the other microbes by producing many food substances like amino acids and polysaccharides. Phototrophic bacteria also play an important role in nitrogen and carbon cycles metabolic systems (Higa and Wididana, 1991; Talaat et al., 2015). Therefore, the symbiosis existing among EM microbes can prevent the putrefactive and pathogenic effect of bad microorganisms and assure good quality silage preventing them from inferior quality feed resources. Furthermore, fermentation of plant materials with EM was proven to improve fiber digestibility (Kannahi and Dhivya, 2014). However, as its CP and energy contents are very low (Tibebu et al., 2018), the fermented teff straw alone cannot satisfy the nutrient requirement of the lambs. As a result, protein as well as energy supplements needs to be incorporated into the fermented tef straw basal diet. Hence, the present experiment was conducted with the objective to study the carcass characteristics and meat quality of *Arsi-Bale* and *Afar* sheep breed lambs fed on *tef* straw ensiled with effective microorganisms and supplemented with concentrates under stall feeding condition.

MATERIALS AND METHODS

Description of the study area

The study was conducted at Addis Ababa University, College of Veterinary Medicine 45 km South -east of Addis Ababa, Ethiopia. It has an altitude of 1900 m above sea level and is located between 8.44°N latitude and 39.02°E longitude. Its average maximum and minimum temperature and annual rainfall are 24.3, 8.9°C and 851 mm, respectively (Getahun, 2014).

Experimental design, animals, treatment diets and their feeding management

Twenty-five lambs of Afar(Af) and Arsi-Bale(AB) breeds were purchased from the respective local markets. They were intact male with the age of 6-9 months.. Dentition and physical appraisal for proper development were the main criteria used for the selection and purchase of the lambs. The purchased lambs were then transported to the study site and acclimatized for fifteen days during which, they were drenched against internal parasites, sprayed against ecto-parasites and vaccinated against anthrax and ovine pasturolosis.

Twenty-one lambs selected for the study from each breed were weighed and divided into seven different weight groups, which represent the replications (blocks) in a randomized complete block design in two factorial arrangement (breed and diet). All animals from each block of each breed were allocated to the experimental diets at random. Thereafter, they were provided with the treatment diets for a fifteen day adaptation period. During the experiment, the lambs were housed in individual animal pens equipped with feeding and watering troughs cleaned every day before offering feed. All animals had free access to water and Rursal RQ mineral blocks (Tecnozoo, https://tecnozoo.it/en/product, Italy). There were three treatment diets, namely, *tef* (*Eragrostistef*) straw silage inoculated with effective microorganisms (EM) offered free choice without supplementation (D1, control); D1 supplementated with wheat bran bokashi (WBB) only (D2) and D1 supplementated with a concentrate feed prepared from WBB and Noug seed cake (NSC,

Table 1. Dry matter (g kg^{-1}) and nutrient (g kg-1DM) composition and estimated ME (MJ kg-1 DM) of experimental feed.

Parameter[a]	Experimental Feed[b]			
	TSS	WBB	NSC	Concentrate mix
DM	282.60	849.00	907.70	874.80
ash	91.00	56.90	153.40	88.30
OM	909.90	943.10	846.60	786.50
CP	58.10	173.10	322.10	211.00
EE	9.60	31.60	42.30	31.90
NDF	792.70	473.10	451.80	405.40
ADF	439.20	386.20	263.30	288.80
IVDOMD	325.60	577.13	329.11	822.92
ME	5.23	8.39	3.93	5.55

[a]ADF=Acid detergent fiber; CP=Crude protein; DM=Dry matter; EE= Ether extract; IVDOMD (g kg-1DM)=In-vitro digestible organic matter in dry matter; OM=Organic matter; NDF=Neutral detergent fiber; ME=Metabolizable energy.
[b]TSS=TS silage; NSC=Noug seed cake; WBB=Wheat bran bokashi

D3). This experiment is a follow up on of a research project comprising TS fermentation (silage making), feeding and digestibility trials. Hence, the EM activation and extension procedures, making of *tef* straw silage (TSS), WBB preparation and nutrient composition of the experimental feeds (Table 1) are discussed elsewhere (Tibebu et al., 2018, 2019). From the TS fermentation experiment, 21 days of ensiling period with 500 mL EM/ 1 kg TS (as feed basis) was found better for making nutritionally good quality TSS. As a result, it was used for the feeding and digestibility trials and consequently in this experiment. The WBB was prepared according to the manual of the EM supplier company. The TSS was prepared by inoculating wet TS with EM solution at a rate of 500 mL/kg and ensiling it for 21 days under shade. WBB was prepared by inoculating dry wheat bran (WB) with EM solution at a rate of 400 mL/kg and ensiling it for 21 days.

The formulation and offer of the concentrate was done to fulfill the minimum CP requirement of the lambs on D_2 and D_3 and offered in a separate trough being divided into two equal portions and provided at 08:00 and 18:00 h before offering basal diet. In order to maintain fulfilling the requirement of the lambs, the feed formulation and offer amount were adjusted fortnightly following their weight change.

Slaughter of animals and carcass measurements

At the end of the feeding and digestion trials, all animals were withdrawn from feed overnight with free access to water, and slaughtered with halal procedure after recording weight just before slaughter (slaughter body weight, SBW). The blood weight was determined as SBW less body weight after bleeding. After the removal of digestive tract and non-carcass components, hot carcass weight (HCW) was recorded including tail fat. Edible and inedible offal components and all non-carcass fat depots (kidney, omental and mesenteric fats) were weighed and recorded. The weight of the digestive tract was recorded while full and empty. Thus, weight of gut-content was computed as the difference between full and empty weights of digestive tract. Empty body weight (EBW) was determined as SBW less gut contents. After the tails were removed and their weight recorded, the carcass was kept in a chilling room (4 to 5°C) for 24 h. Water loss during chilling was considered as carcass chilling shrink (CS) and expressed as percent HCW. Hot carcass dressing percentage on SBW basis(HCDP), cold carcass dressing percentage on SBW basis (CCDP) and cold carcass dressing percentage on EBW basis (DPEB) were calculated as (HCW/SBW)*100; (CCW/SBW)*100 and (HCW/EBW)*100, respectively. Ribeye area (REA) was measured on cold carcass at the 12/13th rib position using transparent paper.

The left and right REA area was traced onto a square paper which was placed on the transparency; the area of the squares (0.25 cm^2 each) that fell within the traced area was measured and those partially outside were estimated and average of the two sides was taken as the REA. All morphometric measurements (anterior and posterior buttock circumference (ABC, PBC), buttock width (BW), carcass length(CL), chest width (CW), leg length (LL), shoulder width (SW) and thorax circumference (TC) were also measured on chilled carcass. Leg compactness (LC) and carcass compactness (CC) were calculated as BW/LL and CCW/CL, respectively.

Meat sample preparation

On both sides of the chilled carcass, a cut was made on the back between the $8^{th}$and 12^{th} rib bone to obtain the *Longissimus dorsi* muscle on which the physicochemical, chemical and sensory eating quality analyses were performed. A total of four samples (two from each side) with a weight ranging from 30 to 63 g were collected. The left side samples were used for determination of color, pH and chemical composition while the right side samples were used for sensory analysis. After taking the color and pH the left side samples were vacuum packaged and stored frozen (<-20°C). The right side samples were aged for 5 days in chilling temperature (4 to 5°C) and stored frozen until evaluated. The frozen samples were thawed overnight in a refrigerator at 4°C before evaluations were commenced.

Determination of physicochemical characteristics of meat

The bag drip loss (BDL) of the meat samples was determined by deducting the weight of the samples after ageing and freezing from the weight of the sample before packing (Pérez-Munuera et al., 2009). The pH measurements were made 45 min (pH_{45}) on the carcass in the *Longissimus dorsi* muscle before chilling and 24 h (pH_{24}) post-mortem on samples taken from chilled carcass using a portable meat pH-meter (HI99163, HANAN instruments) having a sharp penetrating blade over the electrode. The probe was cleaned with distilled water and calibrated with pH 4.1 and 7.1 buffer

Table 2. Carcass characteristics and yield of Arsi-Bale and Afar lambs fed on sole FTS or supplemented with WBB or concentrate mix.

Variable[f]	Treatment (T)[e]			SEMe	Breed (B)[e]		SEM[e]	p-value		
	D1	D2	D3		Af	AB		T	B	T x B
SBW (kg)	16.41[b]	22.59[a]	24.11[a]	0.67	18.68y	23.20x	0.55	0.00	0.00	0.49
EBW (kg)	11.65[b]	18.27[a]	19.73[a]	0.56	14.89y	18.05x	0.45	0.00	0.00	0.36
HCW (kg)	5.46[b]	9.01[a]	10.16[a]	0.42	7.44[b]	8.91x	0.34	0.00	0.01	0.33
CCW (kg)	5.15[b]	8.51[a]	9.76[a]	0.41	7.12[b]	8. 43x	0.33	0.00	0.01	0.33
CS (%)	5.80[a]	5.56[ab]	3.81[b]	0.57	4.36	5.70	0.47	0.038	>0.05	0.92
HCDP (%)	33.31[b]	40.12[a]	41.97[a]	1.07	39.00	37.90	0.87	0.00	0.33	0.58
CCDP (%)	31.41[b]	37.91[a]	40.37[a]	1.08	37.32	35.78	0.88	0.00	0.19	0.57
DPEB (%)	46.92	49.51	51.28[a]	1.40	49.49	49.00	1.14	0.09	0.73	0.05
REA (cm^2)	3.71[c]	5.34[b]	6.75[a]	0.31	4.81y	5.71x	0.26	0.00	0.00	0.49

[e]AB =AB lambs; Af=Afar lambs; D1=Sole tef straw silage; D2= tef straw silage supplemented with WBB alone; D3= tef straw silage supplemented with mix of WBB and NSC; SEM=Standard error of mean.
[f]CCW=Cold carcass weight on SBW basis; CCDP=Cold carcass dressing percentage on SBW basis; CS=Chilling shrinkage; EBW=Empty body weight; DPEB=cold carcass dressing percentage on EBW basis; HCW=Hot carcass weight; HCDP=Hot carcass dressing percentage; SBW= Slaughter body weight; REA=Ribeye area;
[a,b,c]Meandiet effects in a row superscribed by different letters are significantly different; x,y Mean breed effects in a row superscribed by different letters are significantly different.

solutions between each measurement. For color measurements, the cut surface of chilled samples was freshly exposed on flat surface of white background in the measuring room, and allowed to bloom for about 30 to 45 min at ambient temperature. Then, meat color parameters (CIE-values, lightness (L*), redness (a*) and yellowness (b*)) were obtained using a digital colorimeter (HunterLabMiniScan EZ, Serial No. MsEZ1547) calibrated with black and white standardized plates between measurements (AMSA 2012). For both pH and color three readings at different locations per sample were taken and averaged.

Proximate chemical analysis of meat

The determination of moisture, crude protein (CP), fat and ash was performed according to the methods described by the Association of Official Analytical Chemists (AOAC, 1995).

Sensory evaluation for eating quality of meat

Samples were randomly assigned for sensory evaluation by 8 semi-trained panellists according to AMSA (1995). The assessors were teaching staff members, laboratory technicians and post graduate students of food science and technology program of Haramaya University. The samples were tested for tenderness, juiciness, flavor and overall acceptability by rating on a 7 points hedonic scale. The thawed samples were cut into equal pieces, wrapped individually in aluminum foil and oven roasted at 125°C for 45 min (Griffin et al., 1985; as cited by Abdel et al., 2010). Immediately after roasting, the samples were cut into uniform size pieces and held in a food warmer until served. Before the analysis was made the order of service was decided by drawing the code of a sample from its group among the six breeds by diet groups randomly. The pieces of samples were served to the panelists at a time and only once so that every panelist evaluates samples from all lambs randomly. The analysis was done by the same panelists in two consecutive days (21 samples each) at the same time in the afternoon (2:00 to 5:00 pm). The data were reported by the assessors filling a form with pencil. The data were pooled over the panelists for individual lamb and the average of the 8 assessors for an attribute was taken as an observation for the lamb.

Statistical analysis

Data were analyzed using JMP™, The Statistical Discovery Software™ Version 5 and mean differences were tested using LSMean Tukey HSD mean separation tool (SAS, 2002) and considered significant at $p<0.05$. The model used for all carcass and meat quality variables as well as sensory attribute evaluation taking the panelists as block was:

$$Y_{ijk} = \mu + b_i + d_j + (bd)_{ij} + e_{ijk}$$

Where: $\mathbf{Y_{ij}}$= Response variable; $\boldsymbol{\mu}$ = mean of the population; $\mathbf{b_i}$ = the $\mathbf{i}^{th}$ breed effect; $\mathbf{d_j}$= j^{th}diet effect; $\mathbf{(bd)_{ij}}$= the effect of interaction between $\mathbf{i}^{th}$ breed and $\mathbf{j}^{th}$diet; $\mathbf{e_{ijk}}$= random error.

RESULT AND DISCUSSION

Carcass characteristics and yield

Table 2 presents the carcass characteristics and yield attribute of *AB* and *Af* lambs. The *AB* lambs showed higher ($p< 0.05$) SBW, EBW, HCW, CCW and REA than the *Af* lambs while breed did not affect ($p>0.05$) the CS, HCDP, CCDP and DPEB.

Similar to the present study, other studies reported that breed affects the carcass characteristics and yield traits (Flakemore et al., 2015; Kashan et al., 2005 and Macit et al., 2002). In his study where he used supplemented untreated TS basal diet, Getahun (2014) indicated superiority of *Af* over black head *Ogaden* (BHO) lambs in SBW, HCW and HCDP. The diets affected all parameters except DPEB. Both supplements were similar to each

Table 3. Morphmetric carcass measurements of Arsi-Bale and Afar lambs fed on sole TSS or supplemented with WBB or concentrate mix.

Variable[f]	Treatment (T)[e]			SEM[e]	Breed (B)[e]		SEM[e]	p-value		
	D1	D2	D3		Af	AB		T	B	T x B
CL (cm)	36.53^{b}	41.39^{ab}	41.94^{a}	1.57	39.28	40.53	1.28	0.04	0.51	0.87
LL (cm)	27.36	27.86	27.74	0.42	26.23y	29.01^{x}	0.35	0.74	<0.00	0.99
BW (cm)	25.12^{b}	29.52^{a}	29.84^{a}	0.92	26.11y	30.05^{x}	0.75	0.00	0.00	0.80
CW (cm)	10.36^{b}	15.27^{a}	15.50^{a}	1.07	14.37	13.00	0.87	0.00	0.23	0.08
SW (cm)	16.89^{b}	20.23^{a}	21.34^{a}	0.96	19.24	19.68	0.78	0.01	0.72	0.69
TC (cm)	51.34^{b}	62.76^{a}	60.04^{ab}	2.80	55.32	60.42	2.29	0.02	0.14	0.84
ABC (cm)	37.6^{b}	50.7^{a}	49.0^{a}	1.69	44.2	47.0	1.38	0.00	0.22	0.53
PBC (cm)	44.26^{b}	53.34^{a}	53.91^{a}	0.95	48.16y	52.58^{x}	0.78	0.00	0.00	0.79
LC	0.92^{b}	1.06^{a}	1.08^{a}	0.04	1.00	1.04	0.03	0.01	0.46	0.74
CC (kg/cm)	0.14^{b}	0.21^{a}	0.23^{a}	0.01	0.18^{a}	0.20^{a}	0.008	0.00	0.10	0.92

[e]AB =AB lambs; Af=Afar lambs; D1=Sole tef straw silage; D2= tef straw silage supplemented with WBB alone; D3= tef straw silage supplemented with mix of WBB and NSC; SEM=Standard error of mean.
[f]CCW=Cold carcass weight on SBW basis; CCDP=Cold carcass dressing percentage on SBW basis; CS=Chilling shrinkage; EBW=Empty body weight; DPEB=cold carcass dressing percentage on EBW basis; HCW=Hot carcass weight; HCDP=Hot carcass dressing percentage; SBW= Slaughter body weight; REA=Ribeye area;
[a,b,c]Mean diet effects in a row superscribed by different letters are significantly different; x,y Mean breed effects in a row superscribed by different letters are significantly different.

other except for REA, but improved ($p<0.05$) performance over the control. Chilling shrinkage was higher ($p<0.05$) in lambs fed control diet, the lowest being for D_3; implying the positive impact of supplementation. The REA was also improved ($p<0.05$) by supplementation, the higher being for lambs on D_3 followed by D_2 and D_1 groups. The lower CS and higher REA of the D_3 group may show the betterment of WBB and NSC mix than sole WBB supplementation for higher meat yield with minimum storage loss. Similarly, Tesfay and Solomon (2009) found improvement in SBW, EBW, HCW and REA on *Af* rams fed supplemented untreated TS. In his study that compare straws of five faba bean varieties supplemented with concentrate mix of untreated wheat bran and NSC fed to *AB* sheep *ad libitum,* Teklu (2016) found no different carcass characteristics, dressing percentage and REA except SBW and EBW. His report confirmed the lack of difference in carcass characteristics of this study, but opposed the REA result which could be due to the difference in the basal diets.

In another study where supplemented urea treated barley straw was used (*Abebe and Yoseph,* 2015*), AB* sheep scored increasingly higher SBW, EBW, HCW and REA with increasing level of supplementation. Their results support the findings of the present study as all supplemented lambs were higher than the control on these parameters. *Melese et al. (2017)* also *confirmed the same trend of carcass traits improvement on* Washera *sheep due to supplementation of hay by concentrates.* According to Lloyd et al. (1981) and *Žgur et al.* (2003), higher values of carcass traits are apparent for heavier lambs. This is directly in support of the findings of the present study as all higher traits except CS (higher value implies lower quality) were of heavier lambs. The effects of interaction between breed and diet are not discussed, as they did not affect carcass characteristics and yield traits (Table 2). Similarly, other studies done on various sheep breeds and different treatment diets found no interaction effects (Getahun, 2014; Tsegay et al., 2012).

Carcass linear measurements

Table 3 summarizes morphometric carcass measurements. None of the measurements were affected ($p>0.05$) by breed, except LL and BW, which were higher ($p<0.05$) for *AB* lambs. In agreement with this study, Macit et al. (2002) and Popova and Marinova (2013) found no effect of breed on CL. They also found no difference between breeds on LL, as opposed to the present study. Concurring with the present study, two Ethiopian local sheep breeds and their cross with Dorper were found to be different for LL, BW and PBC measurements (Tsegay et al., 2012). The same authors also reported contrary result to the present study of different CL, ABC, TC, BW, SW and CW measurements and similar CC measurements. These differences in result might be attributed to the difference in the breeds and diets used in the experiments. Diet did not affect LL, while the supplemented groups were higher ($p<0.05$) than the control groups and similar to each other for BW, CW, SW, ABC, PBC, LC and CC. Yet, TC of D_2 and CL of D_3 lambs were higher ($p<0.05$) than the control lambs but similar to the other supplemented groups which were also not different ($p>0.05$) from the control groups.

Supporting the results of the present study Majdoub-Mathlouthi et al. (2013) who fed oat hay based diet

Table 4. Proportion (g kg^{-1}) of edible offal components to empty body weight of Arsi-Bale and Afar lambs fed on sole TSS or supplemented with WBB or concentrate mix.

Variable[f]	Treatment (T)[e]			SEM[e]	Breed (B)[e]		SEM[e]	p-value		
	D_1	D_2	D_3		*Af*	*AB*		T	B	T x B
Blood	72.52	60.29	65.07	8.67	60.09	71.82	7.081	0. 60	0.24	0. 90
Heart	5.49	4.88	4.93	0.20	5.06	5.15	0.16	0.06	0.69	0.98
Kidney	3.80	3.53	3.47	0.13	3.60	3.60	0.10	0.14	0.92	0.18
Liver	15.13	17.34	16.00	0.73	15.94	16.31	0.59	0.12	0.71	0.77
ES	39.61	36.87	37.24	2.28	39.40	36.53	1.86	0.65	0.30	0.78
EI	40.32^{ab}	43.72^{a}	38.47^{b}	1.47	37.53^{y}	44.13^{x}	1.20	0.05	0.0004	0.11
Head	97.77^{a}	73.73^{b}	67.77^{b}	2.30	79.69	80.10	1.88	<0.0001	0.75	0.26
Tongue	4.84^{a}	4.65^{ab}	3.72^{b}	0.33	4.59	4.21	0.27	0.04	0.30	0.14
TF	23.63	34.20	38.44	5.30	42.17^{x}	22.38^{y}	4.33	0.126	0.002	0.80
HF	1.12	1.84	1.82	0.28	1.95^{x}	1.24^{y}	0.23	0.12	0.03	0.50
OF	5.55	5.09	6.88	0.75	6.03	5.64	0.61	0.23	0.65	0.84
MF	2.62^{b}	4.74^{ab}	6.79^{a}	0.71	5.00	4.43	0.58	0.001	0.49	0.29
TENCF	9.29^{b}	11.63^{ab}	15.48^{a}	1.11	13.02	11.31	0.91	0.001	0.20	0.93
TEO	239.96	231.04	225.59	5.93	241.07^{x}	223.79^{y}	4.84	0.23	0.02	0.56

[e]AB =AB lambs; Af=Afar lambs; D1=Sole tef straw silage; D2= tef straw silage supplemented with WBB alone; D3= tef straw silage supplemented with mix of WBB and NSC; SEM=Standard error of mean.
[f]EI= Empty intestine; ES=Empty stomach; HF=Heart fat; MF= mesenteric fat; OF= Omentalfat; Means in columns in each effect categories superscribed by different letters are significantly different; TENCF= Total non edible carcass fat; TEO=Total Edible offal
[a,b,c]Mean diet effects in a row superscribed by different letters are significantly different; x,y Mean breed effects in a row superscribed by different letters are significantly different.

supplemented with concentrate to weaned Barbarine lambs, reported that diet affected LC and CC, and did not affect LL and rump circumference. The same authors also found contradictory result of a no diet effect on CL. Likewise, Ahmed et al.(2012) reported no effect of diet on LL of *Af* sheep fed on Rhodes grass hay basal diet supplemented by *Prosopis juliflora* pods or/and leaves. In contrast, Tsegay et al. (2012) reported diet affected LL and did not affect CL, TC and SW. They also found similar results with the present study that diet effect was seen on PBC, ABC, BW, CW and CC. The breed x diet interaction effect was none (p>0.05) for all linear carcass measurements, except CC, for which all supplemented were similar to each other and higher (p<0.05) than the control lambs. However, the control *Af* lambs were not different (p>0.05) from *Af* lambs onD_2.Previous studies also observed no breed and diet interaction effects (Getahun, 2014; Tsegay et al., 2012).

Non-carcass components

Edible offal

Table 4 presents the proportion (g kg^{-1}) of edible offal components to empty body weight of *Arsi-Bale* and *Afar* lambs. The effect of interaction between breed and diet is not presented as it was not seen (p>0.05) for any of the components. Breed affected (p<0.05) only empty intestine (EI), tail fat (TF), heart fat (HF), total edible non carcass fat (TENCF) and total edible offal (TEO) for which the *Af* lambs were higher (p<0.05) than *AB* lambs except for the EI.

In agreement with the present study, Singh et al. (2003) reported breed effect on percentage of TEO. Further, Macit et al. (2002) reported no effect of breed on percentage of head, liver and heart which confirmed the result of the present study. In another study that compared hair and wool type breeds of Mexican sheep, no differences were found on proportion of head, blood and gastro-intestinal viscera (Hernández-Cruz et al., 2009). Their result is in line with the present study except that EI and empty stomach (ES) were reported in combination as gastro-intestinal viscera.

However, a contrary result of genotype affecting percentage of liver, heart and head was found by Cividini et al. (2012). In their study aimed to evaluate effect of days of rest before slaughter, Abebe et al. (2010) found no difference between *AB* and BHO sheep on percentage of head, heart and liver which is similar to the present study. Conversely, genotype was found affecting the same components in an experiment done on the same breeds with the aim of evaluating effect of length of feeding period before slaughter (Merera, 2010).

The proportion of EBW of blood, heart, kidney, liver and ES was affected by neither breed nor diet. The diet effect was found (p<0.05) only on EI, head, tongue, mesenteric fat (MF) and TENCF. Proportion of empty stomach (ES)

Table 5. Proportion (g kg^{-1}) of inedible offal components to empty body weight of Arsi-Bale and Afar lambs fed on sole TSS or supplemented with WBB or concentrate mix.

Variable[f]	Treatment (T)[e]			SEM[e]	Breed (B)[e]		SEM[e]	p-value		
	D_1	D_2	D_3		*Af*	*AB*		T	B	T x B
Lungs	13.68[a]	11.68[b]	10.89[b]	0.45	11.38[y]	12.77[x]	0.37	0.0003	0.01	0.13
Trachea	3.67	3.37	3.63	0.28	3.58	3.54	0.23	0.79	0.87	0.07
Oeso	2.63[a]	2.10[b]	1.98[b]	0.11	2.41[x]	2.07[y]	0.09	0.0003	0.01	0. 90
Spleen	1.94	3.15	2.69	0.23	2.79	2.38	0.19	0.002	0.09	0.33
Panc	1.77	1.35	1.50	0.13	1.58	1.51	0.11	0.09	0.71	0.51
UB	1.48	1.91	2.23	0.28	1.91	1.84	0.23	0.17	0.80	0.09
GB	0.55	0.91	0.97	0.18	0.96	0.67	0.15	0.22	0.18	0.96
Penis	2.85[a]	2.40[b]	2.31[b]	0.11	2.75[x]	2.30[y]	0.09	0.004	0.002	0.66
Testis	13.62	14.17	12.50	3.38	15.86	11.06	2.76	0.94	0.23	0.26
GF	1.77[b]	3.35[a]	3.17[a]	0.31	3.54[x]	1.99[y]	0.25	0.001	<0.0001	0.06
KF	1.77[b]	2.24[b]	3.17[a]	0.23	2.45	2.34	0.18	0.0002	0.68	0.35
Feet	35.89[a]	29.22[b]	26.92[b]	0.86	31.38	30.05	0.70	<0.0001	0.22	0.84
Skin	134.93	137.77	129.73	6.87	132.89	135.16	5.61	0.71	0.801	0.45
TNEO	628.26[a]	448.15[b]	423.09[b]	20.81	485.95	516.02	17.00	<0.0001	0.19	0.72

[e]AB =AB lambs; Af=Afar lambs; D1=Sole tef straw silage; D2= tef straw silage supplemented with WBB alone; D3= tef straw silage supplemented with mix of WBB and NSC; SEM=Standard error of mean. f GB=Gall bladder; GF=Genital fat; KF=kidney fat; Oeso=Oesophagus; Panc=Pancreas UB=Urinary bladder; TNEO=Total inedible offal.
[a,b,c]Mean diet effects in a row superscribed by different letters are significantly different; x,y Mean breed effects in a row superscribed by different letters are significantly different.

was higher ($p<0.05$) in D_2 lambs compared to that of D_3 while D_1 lambs were similar ($p>0.05$) to both groups. The proportion of head of the control lambs was higher ($p<0.05$) than the supplemented lambs which were not different ($p>0.05$) from each other. The control labs had higher ($p>0.05$) proportion of tongue than lambs on D_3 while that of D_2 were not statistically ($p>0.05$) different from both diet groups. The MF and TENCF were found in higher ($p>0.05$) proportion in the D_3 lambs compared to the control lambs while that of D_2 lambs was similar ($p>0.05$) to both groups.

Confirming the present study, Majdoub-Mathlouthi et al. (2013) reported diet affecting proportion of empty gut and not affecting proportion of heart. The same authors also reported a contradictory result to the present study that they found effect of diet on proportion of liver and kidney. However, similar to this study, none diet effect on percentage of TEO was reported (Singh et al., 2003). The reason for the variation seen could be due to the difference in the experimental diet and the genotype of the experimental lambs.

None edible offal

The proportion (g kg^{-1}) of inedible offal components to empty body weight of *AB* and *Af* lambs is presented in Table 5. The breed x diet interaction effect was not seen ($p>0.05$) on any of the components and hence not presented. The proportions to the EBWof lungs, oesophagus (Oeso), penis and genital fat (GF) were affected by breed for which *Af* lambs were higher ($p<0.05$) than the *AB* lambs. Trachea, spleen, pancreas, urinary bladder (UB), gall bladder (GB), testis, kidney fat (KF), feet, skin and total non- edible offal (TNEO) were not affected ($p>0.05$) by breed.

Supporting the result of this study, genotype was reported to have effect on percentage of lungs (Cividini et al., 2012). In contrast to the present study, the same authors found that genotype affected percentage of spleen and skin. However, Singh et al. (2003) reported no effect of breed on percentage of TNEO confirming the results of the present study. Hair and wool type sheep comparison revealed effect on skin and no effect on feet percentage (Hernández-Cruz et al., 2009), which is in disagreement with the present study. Similar to the present study, Macit et al. (2002) found no differences between three sheep breeds on proportion of spleen, testis, feet and skin. However, in contrast to this study, they also found no difference on the proportion of lungs. In contrast to the present study, in an experiment investigating the effect of days of rest before slaughter, *AB* and BHO sheep were reported as different on percentage of spleen and skin (Abebe et al., 2010). As the same time, in support of this study, they also found testis not affected by breed. On the other hand, Merera et al. (2010), in their study examining the impact of length of feeding period before slaughter, revealed a contrasting result of difference between the two sheep breeds on percentage of skin and similar result of no variation on

Table 6. Least square mean physicochemical characteristics and chemical composition of meat (*Longismus dorsi* muscle) of Arsi-Bale and Afar lambs fed on sole TSS or supplemented with WBB or concentrate mix.

Treatment (T)[e]	D_1		D_2		D_3		SEM[e]	p-value		
Breed (B)[e]	*Af*	*AB*	*Af*	*AB*	*Af*	*AB*		T	B	T x B
BDL (%)[f]	13.45	12.66	11.42	8.81	11.28	11.04	1.25	0.07	0.25	0.63
pH[f]										
pH_{45}	6.30	6.34	6.40	6.13	6.34	6.29	1.13	0.91	0.36	0.49
pH_{24}	5.66^{a}	6.19^{a}	5.65^{ab}	5.55^{ab}	5.20^{b}	5.46^{b}	0.22	0.00	0.33	0.79
Color[f]										
L*	32.86^{b}	28.76^{b}	32.28^{ab}	34.98^{ab}	37.03^{a}	34.00^{a}	1.54	0.01	0.25	0.08
a*	12.77	14.08	15.89	13.72	14.18	14.80	0.75	0.17	0.90	0.07
b*	14.80	13.86	14.81	14.33	14.92	14.28	0.41	0.76	0.047	0.85
Moisture (%) and proximate chemical composition (%DM)[f]										
Moisture	72.81^{a}	73.50^{a}	72.20^{ab}	72.75^{ab}	71.72^{b}	71.28^{b}	0.50	0.01	0.52	0.47
CP	20.65	21.65	21.01	20.01	20.12	20.40	0.44	0.12	0.78	0.09
Ash	4.89^{a}	4.84^{a}	4.44^{ab}	4.53^{ab}	4.33^{b}	4.19^{b}	0.18	0.01	0.83	0.84
Fat	6.35^{cx}	3.66^{cy}	9.19^{bx}	8.97^{by}	11.83^{ax}	9.97^{ay}	0.48	0.00	0.00	0.02

[e]Af=Afar Breed; AB=Arsi-Bale Breed; D1=Sole fermented TS; D2 =Fermented TS supplemented with WBB alone; D3=Fermented TS supplemented with mix of WBB and NSC; SEM.=standard error of mean; TS=Tef straw; Values in a row superscribed by different letters are significantly different, letters a,b,c standing for diet and x,y,z standing for breed.
[f]BDL = Bag drip loss; L* Measure Lightness and varies from 100 for perfect white to zero for black, a* measure redness when +ve, grey when zero, green when -ve, b* measure yellowness when +ve, grey when zero, blue when -ve ; pH45 = pH measure taken 45 min after flaying; pH24 = pH measure taken after 24 h chilling; CP = Crude protein;
[a,b,c]Mean diet effects in a row superscribed by different letters are significantly different; x,y Mean breed effects in a row superscribed by different letters are significantly different.

feet and testis percentages. The proportion to the EBW of trachea, spleen, pancreas, UB, GB, testis and skin was not affected (p>0.05) by diet. The proportions of lungs, oesophagus, penis, feet and TNEO were higher (p<0.05) for the control diet lambs than both supplemented groups which were not different (p>0.05) from each other. The supplemented lambs scored similar (p>0.05) to each other but higher (p<0.05) proportion of genital fat (GF) over the control group while proportion of kidney fat (KF) of lambs on D3 was higher (p<0.05) than the control and D2 groups which were not different (p>0.05) from each other.

Contrary to this study, Singh et al. (2003) found similar percentage of TNEO among lambs fed different rations. Majdoub-Mathlouthi et al. (2013) also reported a contradicting result of percentage of testis affected by diet.

Physicochemical characteristics and chemical composition of meat

The physicochemical characteristics and chemical composition of the meat *(Longismus dorsi* muscle) are presented in Table 6. The BDL, pH_{45} and a* color measures were not affected by breed or diet. Breed affected only the b*color measure and fat content being higher (p = 0.05) for *Af* than for *AB* lambs. Diet affected pH_{24} and L* color measure.

Hopkins and Fogarty (1998) found no effect of genotype on pH and color of six genotypes they studied except a pH difference seen among ewes only. Hernández-Cruz et al. (2009) also reported a similar lack of effect of genotype on loin meat color of hair and wool type sheep and *Çelik and Yilmaz (2010) reported no difference between Awassi and their cross with Turkish Merino on meat* $pH_{45\&24}$. Their results confirm the results of the present study with the exception of yellowness, for which meat from *Af* lambs was more (p<0.05) yellow. Contradicting the result of the present study, Blackhead Persian, Dorper and South African mutton Merino were noted with different meat pH_{24} and color (except the a*) values (Chulayo and Muchenje, 2013), while Martínez-Cerezo et al. (2005) found differences in color values between three breeds. Abebe et al. (2010) reported pH_{24} and color (except lightness) variability between *AB* and BHO lambs. This result divergence could be attributed to the differences in the breeds and management of the experimental animals and different experimental treatments applied.

Regarding diet effects, the pH_{24} was found higher (p<0.05) for control diet compared to D_3, while D_2 was not different (p<0.05) from both control and D_3. The lightness (L*) was lower (p<0.05) in control diet than in D_3 while D_2 was not different (p<0.05) from both control and D_3. None of the physicochemical traits were affected by an

Table 7. Least square mean ranking (on 7 points hedonic scale) of sensory eating quality of meat (Longismuss dorsi muscle) of Arsi-Bale and Afar lambs fed on sole TSS or supplemented with WBB or concentrate mix.

Treatment (T)[e]	D_1		D_2		D_3		SEM[e]	p-value		
Breed (B)[e]	*Af*	*AB*	*Af*	*AB*	*Af*	*AB*		T	B	T x B
Tenderness	4.07^{b}	3.97^{b}	5.69^{a}	5.25^{a}	6.18^{a}	5.50^{a}	0.32	0.00	0.13	0.66
Juiciness	3.63^{b}	4.17^{b}	5.13^{a}	4.98^{a}	5.04^{a}	5.25^{a}	0.26	0.00	0.35	0.45
Flavor	3.90^{b}	4.38^{b}	5.57^{a}	5.02^{a}	5.66^{a}	5.41^{a}	0.24	0.00	0.59	0.09
GenrAccep[f]	3.48^{bs}	4.20^{brs}	5.79^{aq}	5.13^{aqr}	5.93^{aq}	5.54^{aq}	0.23	0.00	0.54	0.01

[e]Af=Afar Breed; AB=Arsi-Bale Breed; D1=Sole fermented TS; D2 =Fermented TS supplemented with WBB alone; D3=Fermented TS supplemented with mix of WBB and NSC; SEM.=standard error of mean; TS=Tef straw; fGenrAccep= General Acceptability.
[a,b,c]Mean diet effects in a row superscribed by different letters are significantly different; q,r,s Mean breed x diet interaction effects in a row superscribed by different letters are significantly different;x,y Mean breed effects in a row superscribed by different letters are significantly different.

interaction between breed and diet and hence not discussed.

Color and pH taken at 1 and 24 h post mortem of *Longismus dorsi* meat of *Washera* and Afar sheep were not influenced by level of supplementation and types of feed (Melese et al., 2017; Ahmed et al., 2012). Likewise, Sheridan et al. (2003) reported no effect of diet on color of 8-9-10-rib cut meat of mutton Merino lambs. The result of the present study is in agreement with their result, but pH_{24} and L* color value. With the exception of *AB* lambs on the control diet and *Af* lambs on D_3, the physicochemical values generally fall in the ranges (5.4-5.8 pH_{24}, ≥34 L* and ≥ 9.5 a* values) considered as normal (Chulayo and Muchenje, 2013; Dragomir, 2005, as cited by Majdoub-Mathlouthi et al. (2013); Khliji et al. (2010) and MSA (2015). Generally lambs with heavier SBW exhibited lower pH_{24} and lighter (L*) color (Table 2 and Table 6) confirming the result reported by Majdoub-Mathlouthi et al. (2013).

Chemical composition was not affected by breed except fat content, which was also affected by diet and the interaction as well, whereas moisture and ash contents were affected by diet only. The CP content was not influenced by either of the effects. The moisture and ash contents of the meat from lambs fed the control diet were higher ($p>0.05$) than those of lambs on D_3 while lambs on D_2 were in between with no variation from both. In contrast, the fat content was higher ($p<0.05$) in meat from the lambs fed supplemented diets than those on control, *Af* lambs onD_3 being the highest ($p< 0.05$) followed by *AB*lambs on D_3 which in turn was not different from *Af* lambs onD_2. The fat content of samples from *Af* lambs on the control diet was also higher ($p< 0.05$) than that of *AB* lambs given the same diet. This may lead to the generalization that *Af* lambs were more fatty than the *AB* lambs. This conclusion is confirmed by the fact that *Af* sheep breed was categorized as a breed of fatty carcass (Gizaw, 2009).

Lambs of *Pelibuey* and *Polypay*x *Rambouillet* were compared and found not different on proximate chemical composition of the *L. dorsi* muscle (Peraza-Mercado et al., 2010). This finding is in line with the present study except for fat which was influenced by breed. Substantiating the result of the present study, Abd El-aal and Suliman (2008) reported differences between the diet groups on proximate chemical composition of meat from *L. dorsi* muscle of sheep. The lower fat concentration of meat produced from lambs on the control diet could be associated with their higher moisture content. This is best explained by the inverse relationship that exists between fat and moisture concentrations of carcasses (Stankov et al., 2002).

The sensory eating quality of meat

The sensory eating quality of meat of *AB* and *Af* lambs is summarized in Table 7. The breed of the lambs did not affect any attribute of the sensory eating qualities. Confirming the present finding, Hoffman et al. (2003) reported no effect of genotype on the sensory quality characteristics of *M. semimembranosus* muscle. From their review on factors affecting meat quality traits, Guerrero et al. (2013) found inconsistency among various research works on effect of genotypes on sensory eating quality as some found no effect and others reported large variability between breeds. Yet, they drew a generalization stating that the effect of breed on instrumental and sensory meat quality, such as pH, color, texture and sensory characteristics, is slight, most differences being probably due to differences in maturity or in muscularity levels.

In the present study, however, all the eating quality attributes were higher ($p<0.05$) for meat from the supplemented over the control lambs though they were not different from each other. The control lambs of both breeds were also not different ($p>0.05$) from each other for all attributes of meat sensory eating quality evaluated. Nevertheless, the meat samples from *Af* lambs on D_1 were less ($p>0.05$) tender than that of supplemented *Af* lambs but not different from the other lambs.

The juiciness, flavor and general acceptability were all higher ($p>0.05$) for the supplemented lambs of both breeds compared to the control *Af* lambs but not different

from the control *AB* lambs.

Contrasting the present study, Panea et al. (2011) reported that feed type did not affect sensory characteristics of lamb. Similarly, Sheridan et al. (2003) also did not get any impact of diet on eating quality of meat from Mutton Merino lambs supplemented by either low or high energy concentrates. According to Beriain et al. (2000), there is little variation in toughness in lamb meat, if the management of cooling after slaughter is correct. Nevertheless, there are also other works that reported diet affecting the sensory attributes of meat (Mavimbela et al., 2000; Abd El-aal and Suliman, 2008).

Regardless of the statistical variability, all the supplemented lambs were distinguished as very good meat producers as all evaluated eating quality traits were ranked above five on seven point hedonic scale, the *Af* lambs scoring better value.

Conclusion

Except chilling loss and the dressing percentages for which both breeds were similar, the *Arsi-Bale* lambs were better than the *Afar* lambs in all the carcass characteristics that were also improved by supplementation. Most of the carcass linear measurements were influenced only by diet for which the supplemented lambs performed similar and better than the control. The affected proportion to empty body weight of non -carcass components was higher for *Afar* lambs and found lower for supplemented lambs.

The physicochemical characteristics and chemical composition of meat were similar for both breeds except L*color value and fat content which was higher for *Afar* lambs. As influenced by diet, control lambs scored higher pH_{24}, moisture and ash; and lower L*and fat. All the pH and color scores were in the acceptable standard ranges. All the evaluated sensory eating quality traits were similar and ranked as very good for both breeds' supplemented lambs.

Generally, compared to the *Afar*, the *Arsi-Bale* lambs can produce similar quality but better lean meat yield under the conditions of the present study. Yet, other meat yield and quality parameters not covered by this study such as length of feedlot time required for fulfilling export weight, amino and fatty acid profile and stability of physicochemical characteristics, technological meat quality need to be addressed in future studies.

ETHICS APPROVAL

This study was approved by the Animal Research Ethical Review Committee of College of Veterinary Medicine and Agriculture, Addis Ababa University, responsible for both animal and human ethical concerns:

(1) The feeding trial and slaughter of the animals were done in such a way that welfare of the lambs is fully maintained

(2) The sensory analysis of the meat sample was done by well aware and willing semi trained food science professionals after they get refresher training on meat sensory analysis which made them know the objective of the study, the way the meat samples were collected and stored until tested.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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