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Meat Qualities and Sensory Characteristics of Hararghe and Afar Rams Fed on Varying Energy and Protein Levels in the Diets

Research Article

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ABSTRACT

This study aimed to evaluate instrumental and eating qualities of meat from Afar and Hararghe Highland Rams subjected to different energy and protein levels in the diet. Fifty yearling rams with a mean IBW of 19.31 ± 1.7 kg *(*Mean±SD*)* was randomly distributed into five dietary treatments i.e., minimum energy and protein (mEmP), medium energy and protein (MEMP), medium energy and high protein (MEHP), high energy and medium protein (HEMP), and high Energy and high protein (HEHP) diets in randomized complete block design with 2 × 5 factorial arrangements. The minimum, medium, and high energy diets were: 2.388, 2.866, and 3.344 Mcal/kgDM with the corresponding 10, 16, and 20% crude protein (CP) diets. The diets were formulated in a total mixed ration from wheat bran, maize grain, peanut cake, and pasture hay feed ingredients. There was significant (P<0.01) effects of breed and diets on meat physicochemical parameters (dissected lean, fat, bone, water holding capacity, and chemical compositions), eating qualities (flavor, juiciness and tenderness) and instrumental qualities (Warner–Brazilier shear force and meat color index values [(red (a*); light (L*); yellow (b*)]. Hararghe rams had higher (P<0.01) fat composition, water-holding capacity (WHC), light (L*; 32.4 *vs.* 29.8) and yellow (b*; 9.4 *vs.* 8.4) color index values, and tender meat (19.60 *vs.* 23.38 N/cm^2) as compared to Afar rams. MEHP and HEMP diets were appropriate in promoting better meat quality while MEMP was optimum resulting in desirable meat qualities in both sheep breeds. Meat from both breeds and rams fed on all diets was in the acceptable ranges set for meat quality parameters. Major meat quality defects (dark cutting) observed on slaughtering of free grazing animals directly bought from highland areas has been improved by this feeding and management systems.

KEY WORDS meat color, meat quality defect, meat tenderness, physicochemical parameters.

INTRODUCTION

Animal meat is a crucial part of the human diet as it presents vital nutrients that cannot be easily acquired via vegetables and their derived products (Byers *et al.* 2002). Ethiopia has great potential to make a strong impact on the regional and global markets for meat demand due to its large livestock population (Addis, 2019). Despite the existing potential and growing market demands, productivity and the levels of foreign exchange earnings of the country from this sector are much lower than would be expected (Chala *et al.* 2015). The multiple interactive constraints which livestock production is facing are inadequate supply and poor quality of feeds. Besides, live animal and carcass export rely much on young animals offered to the market from traditional pastoral and agro-pastoral farming systems as the meat from green pasture grazing animals from highland areas have a short shelf life, i.e., darkening and eating quality problems (Tibebu *et al.* 2019). Moreover, 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, and producers have no incentive to raise animals producing high-quality carcass and meat (Solomon *et al.* 2010).

There is, therefore, an urgent need to increase productivity through better feeding and management systems to bridge this gap and support year-round production. Several studies had been conducted to determine the effects of varying protein and energy levels in the diet on lamb performance, carcass, and meat quality measurements (Haddad *et al.* 2001; Bellof and Pallauf, 2004). These authors reported that increasing energy levels in the diet usually resulting in greater gain and fat deposition. More recently, other researchers had reported that an optimum meat quality and yield could be obtained by a dietary energy level in the range 2.3 to 2.5 Mcal ME kg^{-1} (Dove and Milne, 2006; Abdullah and Musallam, 2007) while others have suggested that the optimum range for crude protein (CP) is between 12-16% (Hosseini *et al.* 2008). Nonetheless, studies conducted on sheep fattening in Ethiopia did not consider the impact of different combinations of dietary energy and protein levels formulated in the total mixed ration. Besides, the extent to which this feeding system enables to achieve the desired export market carcass yield and physicochemical meat quality parameters are not so far studied. Consequently, adjusting energy and protein levels in a diet to produce high-quality lamb meat could be beneficial, efficient, and economical for the lamb producers (Abdullah and Musallam, 2007; Hosseini *et al.* 2008).

Hararghe Highland (HS) and Afar (AS) sheep which inhabit highland and lowland areas, are among the major indigenous sheep breeds to compare their meat quality in the stall-feeding system. Most of the sheep reared in the eastern lowlands of Ethiopia are exported as live animals or mutton to the Middle East Countries due to their special merits, such as good meat color, taste, and palatability (Tesfaye and Solomon, 2009; Chala *et al.* 2015). Whereas meat originated from the highland is not preferred for exportation as the carcass and meat color of animals from these areas has dark cutting defects after slaughter (Realini *et al.* 2004). As reported by these authors, it might be related to α-tocopherol (vitamin E) content and chemical compositions of pasture, which makes the meat color are more stable due to its antioxidative effects.

Moreover, Ponnampalam *et al.* (2017) reported that among the components adding to dull cutting meat, transportation stress, nutrition, and feeding management are significant. There are only a few studies aimed at elucidating the causes and possible remedies for the dark cutting meat and eating quality problem held on the export market targeted sheep breeds, i.e., Black Head Ogaden and AS from lowland, and Arsi-Bale from highland (Chala *et al.* 2015; Tibebu *et al.* 2019). As both HS and AS breeds are come from different agro-ecologies and having quite different carcass and meat quality attributes, the present study aimed to evaluate the effects of dietary energy and protein levels on meat quality, physicochemical composition, and sensory characteristics of indigenous sheep breeds of Ethiopia under improved feeding and management systems.

MATERIALS AND METHODS

Ethical approval

All procedures involving animal care and management were carried out in accordance with guidelines for the treatment of animals in Behavioral research and teaching (Sciencedirect and Behaviour, 2012). The protocol was approved by the research and ethics committee of school of animal and range sciences, Haramaya University, Ethiopia (SARSc 46/050 and dated on March 03/2019).

Experimental site

This experiment was conducted at goat farm of Haramaya University, which is located 515 km east of the capital, Addis Ababa. The site is situated at an altitude of 2006 meters above sea level, 9˚ 41'N latitude, and 42˚ 4'E longitude. The mean annual rainfall of the area is 790 mm and the annual mean temperature of 17 ˚C with mean minimum and maximum temperatures of 14 and 23.4 ˚C, respectively (Kbrom *et al.* 2016).

Experimental animals, diet preparation and feeding management

A total of 50 yearling intact rams, 25 from each breed with a mean initial body weight of 19.31 ± 1.7 kg was used for this study. Hararghe and Afar yearling rams were purchased from the local markets of Deder and Amibara, respectively. After arrival at the research site, they were ear-tagged for identification. During the quarantine period of 21 days, they were drenched with a broad spectrum anthelmintic (Albendazole) drug against internal parasites and dipped in acaricide against external parasites. Besides, they were vaccinated against common diseases (Anthrax and Pasteurellosis) as per the recommendation for commercial sheep production (Pugh and Baird, 2012). The diets were formulated in a total mixed ration on DM basis from wheat bran, ground maize grain, groundnut cake, grass hay, common salt, vitamin and mineral premixes (Table 1). The diets were divided into two equal meals and offered at 08:00 a.m. and 04:00 p.m. at a fixed rate of 3% of their body weight on DM basis. The quantities of diets offered were revised biweekly based on their body weight changes.

Table 1 Ingredients and chemical composition of experimental diets

Variables	Energy and protein combinations in each treatment				
	mEmP	MEMP	MEHP	HEMP	HEHP
Ingredients (%)					
Grass hay	50	40	34	16	19
Ground maize grain	18	26	21	48	40
Wheat bran	14	12	8	16	9
Groundnut cake	16	20	35	18	30
Common salt	1	1	1	1	1
Vitamin and mineral pre mix	1	1	1	1	1
Chemical composition (%)					
DM	93.85	92.46	91.35	90.44	90.15
OM	91.34	92.88	93.69	94.45	94.70
CP	10.07	15.64	19.64	15.72	19.77
NDF	55.05	48.70	42.10	47.36	47.86
ADF	19.11	16.49	13.38	15.03	14.28
ADL	6.70	4.34	3.37	3.02	2.80
Ash	8.66	7.12	6.31	5.55	5.30

mEmP: minimum energy and minimum protein; MEMP: medium energy and medium protein; MEHP: medium energy and high protein; HEMP: high energy and medium protein and HEHP: high energy and high protein.
DM: dry matter (fed basis); OM: organic matter (% DM); CP: crude protein (% DM); NDF: neutral detergent fiber (% DM), ADF: acid detergent fiber (%DM); ADL: acid detergent lignin (% DM); NDF: neutral detergent fiber (% DM).

Ahead of the actual experiment, the rams were acclimatized to the experimental diets and individual pen management for 14 days by randomly assigning them to their respective dietary treatment groups. The animals had free access to clean drinking water in their respective pen throughout the experimental period. They were carefully observed for the occurrence of any health-related problems and records were taken throughout the entire experiment.

Experimental design and treatments

The experimental design used was a randomized completely blocked design (RCBD) with a 2 × 5 factorial arrangement in which the animals were grouped based on their initial body weight and randomly assigned to each dietary treatment. In this case, five replications from each breed per block and dietary treatment exist. Yearling rams were fed these five dietary groups having different combinations of energy and protein levels during 90 days.

i) Minimum energy and minimum protein diet (mEmP; 2.388 Mcal/kg DM and 10% CP). This diet was used as positive control whereas the rest were test diets.
ii) Medium energy and medium protein diets (MEMP; 2.866 Mcal/kg DM and 16% CP).
iii) Medium energy and high protein (MEHP; 2.866 Mcal/kg DM and 20% CP).
iv) High energy and medium protein (HEMP; 3.344 Mcal/kg DM and 16% CP).
v) High energy and high protein (HEHP; 3.344 Mcal/kg DM and 20% CP).

Preparation of these dietary treatment groups was made following the recommended ranges of dietary energy and protein levels for sheep (Ensminger and Parker, 1986; NRC, 2007). According to these authors, the diets having crude protein categories of < 12%, 12% - 20%, and > 20% were classified as low, medium, and high protein source diets, respectively.

In the same way, the diets with metabolizable energy categories of < 2.15, 2.15 - 2.868, and > 2.868 Mcal/kg DM were classified as low, medium, and high energy diets respectively for commercial fattening of rams through 90 days of feeding.

Meat samples preparation and meat quality parameters measurement

Based on the standard procedure of AOAC (2005) recommended for meat and meat products, four meat samples (steaks) of 2.5 cm thick were taken i.e. two meat sub samples from the right and the other two meat sub samples were from left side (upper and lower regions) of the whole carcass of each animal's longissimus dorsi muscles between 10^{th} to 13^{th} rib positions relative to rib eye area measurement. The first two meat samples were used for pH, color, water losing parameters (drip, thawing, and cooking loss), and instrumental meat tenderness (Warner-Brazilier shear force) measurements. Whereas, the second two meat sub samples (left side) were kept in zipper plastic bags for further meat quality parameters i.e. proximate analysis, meat sensory characteristics as described by Sullivan and Calkins (2011).

The water losing parameters (thawing, cooking, and drip losses) were estimated to examine the meat quality in terms of its water holding capacity. The water loss on thawing is termed as thawing loss. Each frozen meat sample was weighed (W1), thawed at 4 ˚C for 24 h. The bag was opened and the muscles were then blotted dry with filter paper and weighed (W2).

Thawing loss (%) was calculated as; ([W1–W2/W1) × 100. Drip loss was determined using the suspension method of Torres Filho *et al*. (2017). Meat samples taken from each ram was put into the netting and suspended in a plastic bag, ensuring that there was no contact between the sample and the bag. Samples were stored in this manner at 4 ˚C for 24 h. The weight of each sample was recorded before and after being suspended. Drip loss was expressed as a percentage of weight loss after suspension relative to the initial weight of the slice.

For determination of cooking loss, samples were weighed (W3) in the watertight bags and then cooked in the thermostatically controlled water bath set at 75 ˚C for 60 min as described by Hoffman *et al*. (2003). Then, meat samples were cooled for 4 h, and samples were taken from the bags dried with the filter paper, and reweighed (W4). Cooking loss was expressed as the percentage of water loss related to initial weight: ([W3–W4]/W3) × 100.

Instrumental meat tenderness values were evaluated on each cooked steak dissected into three subsamples or cores of 1cm^2 cross-section parallel to the muscle fiber grain. Each sub-sample (core) obtained from the cooked sample was sheared twice perpendicular to the muscle fiber orientation, using a Warner-Brazilier shear machine (G-R Electric Manufacturing Co., Manhattan, KS). An average shear force of all sub-samples was calculated and recorded as a maximum shear force value for a particular meat sample described by Sullivan and Calkins (2011).

Meat physicochemical characteristics

The remaining parts of the left half-carcasses were dissected into lean, fat, and bone to estimate the physical composition of the left half and whole carcass components. The ultimate pH at 24 hrs. measurements was carried out on meat samples taken after 24 hours of chilling using a portable meat pH meter (Hanna Instruments HI-99163N**)** and calibrated with pH 4.01 and 7.01 buffers after each batch of measurements. The measurement was carried out in three replicates from each meat sample by inserting the electrode deep inside the meat sample into three different locations and the average value was recorded for each sample (AMSA, 2016).

Meat color measurements were performed on the meat samples' surface after 30 minutes of aerobic exposure. A portable Hunter laboratory colorimeter (Mini Scan EZ spectrophotometer) was used to measure the three numerical color measurements lightness (L*), Redness (a*), and Yellowness (b*), respectively (AMSA, 2016).

The spectrophotometer had been calibrated before analyzing the samples against white and black standards. In addition, Chroma (C*) or color intensity or saturation was calculated as $C^*ab= (a^{*2}+b^{*\,2})^{1/2}$, and hue angle or the color descriptor was calculated as h^* ab= arch tan (b*/a*) or tan-1 (b*/a*). The data were collected from the spectrophotometer screen after conducting measurement at three different points of each sample and then average values were computed.

Taste panels selection and facilities

Sensory analysis was performed at Haramaya University Resource Center using consumer panelists. Out of 15 candidates, nine eligible panelists of age between 28 and 40 years were selected based on the set criteria and administered a screening questionnaire. They received training verbal instructions, and orientation before being seated for cooked product evaluation (Muela *et al*. 2010). Sensory evaluation was conducted in a room where disturbance to sensory stimuli was minimized, away from distracting noise, odors, and neutral lighting. Influence and disturbance from fellow panel members and other personnel were minimized.

Each panelist involved in the test was given a score sheet, where they marked their findings of the sensory attributes of the meat samples. Moreover, each member was provided with utensils including a fork, a knife, a paper plate, napkins, one glass cup with warm water for mouth cleansing after each sample testing, and one plastic garbage for spitting into as per AMSA (2016) guide line.

Sample preparation and serving to the panelists

The meat samples designated for panelists' product testing had been thawed at 4 ˚C overnight and then individually foil-wrapped with its independent code. The electric oven was preheated at 175 ˚C to an internal temperature of 40 ˚C using an automatic cooking temperature and time monitoring UV thermometer. The samples were put on cooking tray, and placed in different layers of the cooking oven. Then, flipping and complete cooking to a final internal temperature of 71 ˚C for 30 minutes. At the time of serving, the samples were unwrapped and set directly on the plates, then presented to panelists in a sequential monadic manner.

The panelists independently rated the flavor, tenderness, juiciness and overall acceptance of samples on a 7-point hedonic scale from 1= like very much, 2= dislike moderately, 3= dislike slightly, 4= neither like nor dislike, 5= like slightly, 6= like moderately, 7= like very much, respectively (Thompson *et al*. 2005).

Laboratory analysis

The meat samples taken for meat nutritional composition (proximate analysis) were thawed at room temperature (20 ˚C), ground separately in meat grinding apparatus. Then, the samples were homogenized, sub-sampled, and placed in a forced ventilation oven at 55 ˚C for 72 hours. After this procedure, the samples were defatted by extraction with ether in a Soxhilet apparatus (AOAC, 2005) to obtain total lipid. After extraction, the samples were ground in a ball mill and stored in closed containers. The dry matter contents were determined by placing samples in an oven at 105 ˚C until a constant weight was reached. The ash and CP levels were determined on fat-free samples through the Kjeldahl method (CP=N×6.25) as per AOAC (2005) procedure.

Statistical analysis

Data were processed and analyzed using the general linear model procedures of SAS 9.4 versions (SAS, 2012) to determine the effect of breed and dietary treatment on the measured meat quality parameters like instrumental, meat-eating quality, and water holding capacity (WHC). Adjusted Tukey test (P<0.05) was used to locate means that are significantly different. The statistical model applied for the above data set was:

$$Y_{ijkl}: \mu + D_i + C_j + B_k + (D\times B)_{ik} + e_{ijkl}$$

Where:
Y_{ijkl}: response variable.
μ: overall mean.
D_i: effect of being in diet i.
C_j: effect of being in block j.
B_k: effect of being in breed k.
$(D\times B)_{ik}$: interaction between breeds and diets levels.
e_{ijkl}: random error.

The interaction and main effects' least-square means were presented and discussed based on their existences. The Pearson correlations analysis was conducted for meat pH and water holding parameters using PROC COR. Moreover, bar graph plotting was conducted for physical meat composition across experimental periods using Microsoft Excel.

RESULTS AND DISCUSSION

Effects of breed and diet on physicochemical meat quality characteristics

In this study, there were significant breed effects in which Afar rams had higher water, mineral, and protein contents, and dissected lean composition as compared to Hararghe rams (P<0.001) while fat (ether extract) and dry matter content, bone and dissected fat composition were higher for the later sheep breed as shown in Table 2 and Table 3, respectively. This variation might be associated with the ability of Afar rams to produce leaner meat than Hararghe rams, which is a preferable meat characteristic to consumers (Table 3 and Figure1). The results are also similar to with previous studies reported that breed or genotype is an important factor influencing rams' meat quality (Martínez-Cerezo *et al*. 2005; Şirin *et al*. 2017). In line with this, Mahgoub *et al*. (2000) reported that as slaughter body weight increases, so does the fat levels with declining trends of meat moisture and protein contents while it had no effects on ash content in Omani sheep meat chemical composition analysis. However, other researchers had reported that an optimum meat quality and yield can be obtained by a dietary energy level in the range 2.3 to 2.5 Mcal ME kg^{-1} (Dove and Milne, 2006) whilst others have suggested that the optimum range for crude protein is between 12-16%.

The increasing trends of lean composition was observed when energy and protein densities increase from mEmP diets to MEHP test diet while a declining trend was observed on higher energy and protein densities in HEMP and HEHP dietary treatments. Accordingly, the highest (P<0.001) fat and DM contents recorded by rams fed on HEHP diets and followed by HEMP > MEHP > MEMP while control diet-fed animals had recorded the least fat content and comparable dry matter composition. However, the highest (P<0.001) lean composition, moisture, protein, and ash contents was recorded by yearling rams fed on MEMP diet and followed by MEHP > HEMP > HEHP diets fed animals. Interaction effects of breeds and diets were observed (P>0.05) on minerals, water, DM, and fat contents. The significant effects of energy and protein levels on meat chemical characteristics on the area of longissimus dorsi muscle agree with the findings of Dziba *et al*. (2007). This study results also conform to the findings of Mahgoub and Lu, (2004) who reported that increasing dietary energy levels from 8.67 to 11.22 MJ ME/kg DM, carcass fat content increase while water, ash, and protein levels decline for both experimental sheep and goats. Milis *et al*. (2005) showed that high dietary energy had negatively affected the amount of protein and ash on the carcass but increased kidney size and pelvic fat content.

Table 2 Meat chemical composition of Hararghe and Afar rams

Measurements (%)	Breed (B)		Diets (D)					SEM	P-values		
	HS	AS	mEmP	MEMP	MEHP	HEMP	HEHP		B	D	B × D
Crude protein	19.92[b]	24.65[a]	22.83[ba]	24.34[a]	23.56[a]	21.14[b]	19.52[c]	0.38	**	**	NS
Ether extract	3.92[a]	2.84[b]	2.08[e]	2.68[d]	3.40[c]	3.94[b]	5.20[a]	0.03	**	**	*
Ash	2.40[b]	3.09[a]	2.88[b]	3.15[a]	2.70[bc]	2.55[c]	2.20[d]	0.03	**	**	*
Moisture	68.94[b]	73.35[a]	72.64[b]	74.77[a]	71.06[c]	69.84[d]	68.01[e]	0.32	**	**	*
Dry matter	31.06[a]	26.65[b]	27.36[d]	25.23[e]	28.94[c]	30.16[b]	31.99[a]	0.24	**	**	*

HS: Hararghe highland lambs; AS: Afar lambs; mEmP: minimum energy and minimum protein; MEMP: medium energy and medium protein; MEHP: medium energy and high protein; HEMP: high energy and medium protein and HEHP: high energy and high protein.
B × D: interaction between breed and diets.
* (P<0.05) and ** (P<0.01).
SEM: standard error of the means.
NS: non significant.

Table 3 Dissected left half carcasses and estimated whole carcass components

Measurements (%)	Breed (B)		Diet (D)					SEM	P-values		
	HS	AS	mEmP	MEMP	MEHP	HEMP	HEHP		B	D	B × D
LHC weight	6.75[b]	6.40[a]	5.73[c]	6.59[b]	8.61[a]	7.16[b]	6.70[b]	0.15	*	**	NS
Lean	52.05[b]	60.20[a]	60.74[a]	57.92[b]	54.14[c]	51.05[d]	46.51[e]	0.57	**	**	NS
Bone	28.11[a]	23.30[b]	22.60	22.58	23.23	22.91	23.18	0.03	**	NS	NS
Dissected fat	20.22[a]	16.50[b]	16.66[d]	19.50[c]	22.63[e]	26.04[b]	30.31[a]	0.35	***	***	NS
Weight WC	13.85[b]	12.40[a]	11.00[d]	12.43[c]	15.33[a]	14.41[b]	14.62[b]	0.27	**	**	NS
Lean	50.50[b]	62.25[a]	64.60[a]	58.91[ab]	55.06[b]	46.89[c]	37.99[d]	0.28	**	***	NS
Bone	28.30[a]	22.48[b]	20.40	20.26	19.58	20.01	19.60	0.39	**	NS	*
Dissected Fat	21.20[a]	15.27[b]	15.00[e]	20.89[d]	25.36[c]	33.10[b]	42.41[a]	0.35	**	***	NS

LHC: left half carcass; WC: whole carcass weight; Dissected fat: carcass fat composition without including tail fat; HS: Hararghe highland lambs; AS: Afar lambs; mEmP: minimum energy and minimum protein; MEMP: medium energy and medium protein; MEHP: medium energy and high protein; HEMP: high energy and medium protein and HEHP: high energy and high protein.
B × D: interaction between breed and diets.
* (P<0.05); ** (P<0.01) and *** (P<0.001).
SEM: standard error of the means.
NS: non significant.

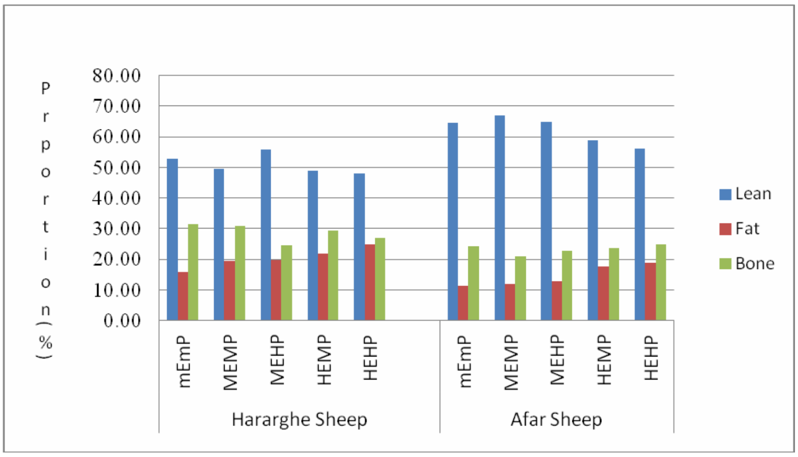

Figure 1 Effects of breeds and diets on physical meat composition

However, low energy density animals had higher carcass protein (as % DM) than both medium and high energy density animals as reported by Mahgoub *et al*. (2000) in Omani sheep. This is in line with reports in Mehraban rams (Ebrahimi *et al*. 2007) where lower or optimum energy levels with medium to high levels of protein inclusion in diets would enhance lean meat proportion, protein, and moisture content.

However, higher energy levels with lower protein inclusion in diets would enhance back fat depth, visceral fat content but reduce moisture, protein, and lean meat proportion. The main parameters of meat quality are lean and fat proportions, lean: bone ratio, and saleable meat yield. Hence, the commercial value of sheep carcasses is influenced by the proportion of muscle, fat, and bone in a wholesale cut, and consumers require meat with more lean, less fat (the minimal fat level required to maintain juiciness and flavor), and consistent quality (Martínez-Cerezo *et al.* 2005).

In the same way, the highest (P<0.001) fat and meat DM contents recorded by yearling rams fed on HEHP diets followed by HEMP > MEHP > MEMP while control diet-fed animals had recorded the least fat content and comparable dry matter composition. Nevertheless, the other meat chemical composition parameters like moisture, protein, and ash contents were the highest in rams fed on mEmP diet and followed by MEMP > MEHP > HEMP > HEHP. This variation might be associated with the ability of Afar rams to produce leaner meat than Hararghe rams, which is a preferable meat characteristic to consumers (Table 3 and Figure1).

The main meat quality parameters are lean and fat proportions, lean: bone ratio, and saleable meat yield. The commercial value of sheep carcasses is influenced by the proportion of muscle, fat, and bone in a wholesale cut, and consumers require meat with more lean, less fat, and consistent quality (Martínez-Cerezo *et al.* 2005). In line with this, Mahgoub *et al.* (2000) reported that the declining trends of meat moisture and protein contents with an increasing slaughter body weight and significant no effect on ash content in Omani sheep meat chemical analysis.

Likewise, other researchers had reported that an optimum meat quality and yield could be obtained by a dietary energy level in the range 2.3 to 2.5 Mcal ME/kg DM (Dove and Milne, 2006) while others have suggested that the optimum range for CP is between 12-16%. The results of this study also conform to the findings of Mahgoub and Lu (2004), who reported that increasing dietary energy levels from 8.67 to 11.22 MJ ME/kg DM increase carcass fat content while water, ash, and protein levels of both experimental sheep and goats decrease. It was stated in the literature that while a high dietary energy level of diet had negatively affected the amount of protein and ash content of carcasses. Animals fed with low dietary energy level had a higher amount of protein than fed with both medium and high dietary energy level (Mahgoub *et al.* 2000; Milis *et al.* 2005). In line with these reports, Ebrahimi *et al.* (2007) stated that lower or optimum energy levels with medium to high dietary protein levels inclusion in the diet would enhance lean meat proportion, protein, and moisture content of Mehraban male lambs. Nevertheless, higher energy levels with lower dietary protein levels inclusion in the diets would enhance back fat depth and visceral fat content while reducing the moisture, protein, and lean meat proportion.

Effects of diet and breed on meat color, pH, tenderness and water losing parameters

Meat from Hararghe yearling rams had higher (P<0.001) lightness (L*), yellowness (b*), and chroma (C*;-color saturation or intensity of color) color index values by 2.6, 1.0, 1.43, respectively as compared to Afar rams. Where as, Afar rams' meat color had higher (P<0.001) redness (a*) values by 1.2 than Hararghe lambs (Table 5). However, Hararghe rams had higher (P<0.001) back fat thickness (mm). This could be associated with higher intramuscular fat and lower myoglobin content in Hararghe rams' meat. In line with this study, Hui *et al.* (2012) reported that meat color differences between species are largely due to the differences in intramuscular fat content, quantity, type, and the chemical state of myoglobin muscle which is again affected by factors such as exercise and diet of the animal as well as genetic and environmental factors.

As reported by many previous studies (Realini *et al.* 2004; Ponnampalam *et al.* 2017), green pasture grazing beef and small ruminant in highland areas had dark cutting meat (meat color defects) after slaughtering, and meat blooming. According to these authors, the possible reason could be due to the presence of vitamin E (α-tocopherol) precursor in the green pasture which make free grazing animals' meat color stable. Hence, this study had improved the meat color defect of Hararghe rams fed on different dietary energy and protein levels formulated in a total mixed ration. In this regard, the Ethiopia's meat production and the levels of foreign exchange earnings primarily limited on low land areas had been improved and confirmed that diets and better feeding managements have great effects on meat color and pH values of highland animals.

This study indicated that there were significant (P<0.001) diets effects with rams fed on HEHP diets had a higher lightness, yellowness, and chroma color values followed by HEMP, MEHP, MEMP, and mEmP diets fed rams (Table 3). Whereas the inverse trend was observed on red color value as rams fed on higher energy and protein levels (HEHP, HEMP) diets had more subcutaneous and visceral fats as compared to MEMP and MEHP diets fed rams which had recorded more intramuscular fat contents. In line with this study, previous studies (Hui *et al.* 2012; Ponnampalam *et al.* 2017) reported that meat color is influenced by intramuscular fat content, quantity, type, and the chemical state of myoglobin muscle which is again affected by factors such as exercise and diet of the animal as well as genetic and environmental factors.

There were no significant differences (P>0.05) in ultimate pH values of meat from both sheep breeds, and rams fed on different dietary treatment groups (Table 2). This result showed that the rams were slaughtered under stress-free conditions, and the rigor mortis occurred accurately and slaughtering procedures were compatible with the standards. In line with this, previous studies reported that the meat ultimate pH value is not affected by the type of diets but depends on the level of stress-induced during the pre-slaughter procedure, and the rate of post-mortem glycolysis (Velasco *et al.* 2004).

The very fast glycolysis leads to a rapid drop in pH (<5.4) which results in pale, soft, and exudative (PSE), while slow glycolysis leads to high ultimate pH (>6.0) resulting in dark, firm and dry (DFD) or dark cutting meat as reported by previous studies (Pratiwi *et al.* 2007; Knox *et al.* 2008). Hence, such abnormal pH values can alter the quality of meat, especially in terms of color, tenderness, and WHC. In this study, the ultimate pH at 24 h after slaughter for both breeds and rams fed on different dietary treatment groups had been within the range of 5.68 and 5.85. In line with this, Tejeda *et al.* (2008) reported that the recommended normal (unstressed animal) ultimate meat pH at 24 h would be within the ranges of 5.5 to 5.7, and the range between 5.7 to 5.97 might be considered within the desired range to avoid problems in meat quality.

Furthermore, significant (P<0.001) effects of breed were observed on water holding and Warner-Brazilier (WB) shear values with Afar rams' meat had higher (P<0.001) cooking, drip and thawing losses, and shear force (N/cm^2) values by 2.59, 3.81, 2.12%, and 3.78 (N/cm^2), respectively than meat from Hararghe rams (Table 3). The water released can be described as drip loss, cook loss, thawing losses, and these are inversely related to WHC (Santos-Silva *et al.* 2002). Besides, meat obtained from rams managed under control diet (mEmP) and MEMP test diet had higher (P<0.001) cooking, drip and thawing losses, shear force values and followed by rams fed on MEHP > HEMP > HEHP diets. This implied that Hararghe rams' meat and those fed on HEMP and HEHP diets had recorded minimum shear force values (having more tender meat), and high-WHC. The real effect of fatness (subcutaneous and intramuscular fat) in increasing the tenderness of animal carcasses was a result of the ability of fat to insulate muscle fibers against cold-shock during postmortem chilling (Sañudo *et al.* 2000; Díaz *et al.* 2008).

Many previous studies reported that rams meat with shear force values less than 4.9 kg/cm^2 (49 N), and cooking loss below 30% is considered as tender and quality meat with desirable WHC (Hopkins *et al.* 2006). As the maximum shear force values and cooking loss recorded in this study are below the recommended peak values, meat from both sheep breeds, and rams fed on all dietary treatment groups was tender and quality meat. In addition, previous studies reported that meat tenderness and WHC increased with increasing slaughter body weight and carcass fatness (Hopkins *et al.* 2006; Sullivan and Calkins, 2011). Meat tenderness could be affected by the structure of the connective tissue, carcass fatness, and collagen levels of meat (Sañudo *et al.* 2000; Díaz *et al.* 2002). Contrary to this study results, Santos-Silva *et al.* (2002) and Cañeque *et al.* (2003) reported that diet levels did not affect the meat tenderness measured in terms of Warner-Braziler shear values. In this study, correlation coefficients of ultimate pH, shear force values, and WHC presented in Table 4. The ultimate pH values of meat from Hararghe rams had medium (P<0.01) direct correlation with drip and thawing losses, and shear force values but it had strong correlation with cooking loss. However, ultimate pH values of Afar rams' meat had medium direct correlation with all water holding parameters. Similarly, shear force values of the meat from Hararghe rams had medium (P<0.01) direct correlation with ultimate pH (24 hrs) and water holding parameters. In line with this study, Tejeda *et al.* (2008) reported that pH value of meat is closely correlated with many other properties of meat such as WHC, color, tenderness, flavor, and shelf-life. An increase in the degree of shrinkage during cooking is directly correlated with a loss of juiciness upon consumption. Most previous studies indicated that juiciness had shown a closer correlation with fat content than water holding parameters (Sañudo *et al.* 2000; Muela *et al.* 2010). Likewise, Tenderness and juiciness are closely related; the more tender the meat, the more quickly the juices are released by chewing, and the juicier the meat appears.

Effects of diet and breed on meat sensory characteristics

This study results indicated that panelists gave a higher score (P<0.001) to meat from Hararghe yearling rams in all sensory traits as compared to Afar rams (Table 6). Overall acceptability scores given to Hararghe yearling rams could be a reflection of the meat tenderness, fat content, flavor intensity, and quality perception of panelists. In line with this study results, Muela *et al.* (2010) reported that meat from fattier carcasses had higher flavor and juiciness intensity. On the other hand, panelists gave the highest scores in all taste panel traits (flavour, juiciness, tenderness, and overall acceptability) for meat from rams fed on HEMP diet and followed by MEHP > HEHP = MEMP > mEmP (Table 6). Overall acceptability scores given to animals fed on HEMP could be a reflection of the meat tenderness, intramuscular fat content, flavor intensity, and quality perception of panelists. However, animals fed on the HEHP diet accumulated more subcutaneous, organ, and visceral fats than intramuscular and intermuscular fats. The meat quality perception of panelists indicated that there was an interaction of breeds and diets on all sensory traits except for flavor intensity and quality. This is in agreement with the previous study report (Ekiz *et al.* 2012).

In this study, the correlation coefficient of meat-eating quality parameters (tenderness, juiciness, flavor and overall acceptability) was presented in Table 7. Sensory tenderness had a strong (P<0.001) direct correlation with flavor and juiciness of meat tasted from both breeds of lambs.

Table 4 Meat pH, color, and water losing parameters of Hararghe and Afar lambs

Measurements	Breed (B)		Diet (D)					SEM	P-values		
	HS	AS	mEmP	MEMP	MEHP	HEMP	HEHP		B	D	B × D
SW (kg)	29.35[a]	26.65[b]	26.4[e]	29.3[c]	30.2[b]	31.3[a]	27.8[d]	0.20	***	***	NS
pH of 45 min	6.22	6.21	6.21	6.21	6.18	6.20	6.29	0.01	NS	NS	*
Meat pH $_{24hrs}$	5.78	5.74	5.68	5.71	5.76	5.80	5.85	0.01	NS	NS	NS
L*	32.4[a]	29.8[b]	28.0[e]	30.3[d]	32.5[a]	33.1[a]	31.1[b]	0.17	**	**	NS
a*	11.4[b]	12.6[a]	13.2[a]	12.8[a]	11.6[b]	11.4[b]	9.2[c]	0.07	**	**	NS
b*	9.4[a]	8.4[b]	7.4[d]	8.6[c]	9.8[a]	10.4[a]	9.1[b]	0.05	**	**	**
C*	14.87[a]	13.44[b]	12.27[d]	13.21[c]	15.88[a]	16.04[a]	14.54[b]	0.13	**	**	NS
h*	65.10	66.15	64.56	65.40	68	67.8	66.20	1.01	NS	NS	NS
Cooking loss (%)	20.02[b]	22.61[a]	23.57[a]	22.62[b]	19.85[d]	19.52[d]	20.21[c]	0.25	**	**	NS
Thawing loss (%)	8.27[b]	10.39[a]	11.96[a]	10.69[b]	7.70[d]	7.79[d]	8.50[c]	0.09	**	**	**
Drip Loss (%)	15.01[b]	18.82[a]	19.69[a]	18.34[b]	15.42[d]	14.92[d]	16.85[c]	0.32	***	**	NS
Shear force (N/cm^2)	19.60[b]	23.38[a]	24.32[a]	22.40[b]	20.86[c]	19.84[d]	20.25[d]	0.32	***	**	NS
Back fat thickness (mm)	1.01[a]	0.64[b]	0.58[e]	0.71[d]	0.85[c]	0.96[b]	1.03[a]	0.022	***	**	NS

SW: slaughter weight; *L**: lightness; *a**: redness; *b**: yellowness; C: chroma; h*: hue; HS: Hararghe highland lambs; AS: Afar lambs; mEmP: minimum energy and minimum protein; MEMP: medium energy and medium protein; MEHP: medium energy and high protein; HEMP: high energy and medium protein and HEHP: high energy and high protein.
B × D: interaction between breed and diets.
* (P<0.05); ** (P<0.01) and *** (P<0.001).
SEM: standard error of the means.
NS: non significant.

Table 5 Correlation coefficients of pH with water losing parameters and shear forces

HS (upper diagonal) AS (lower diagonal)	pH$_{24 hrs.}$	Drip loss	Thawing loss	Cooking loss	Shear forces
pH 24 hrs.	-	0.90*	0.95*	0.98**	0.92*
Drip losses	0.89*	-	0.75[ns]	0.86*	0.86*
Thawing losses	0.89*	0.88*	-	0.97**	0.91*
Cooking losses	0.86*	0.93*	0.97**	-	0.95*
Shear forces	0.56[ns]	0.58[ns]	0.86[ns]	0.81[ns]	-

HS: Hararghe highland lambs and AS: Afar lambs.
* (P<0.05); ** (P<0.01) and *** (P<0.001).
NS: non significant.

Table 6 Meat sensory characteristics of Hararghe and Afar yearling rams

Attributes	Breed (B)		Diet (D)					SEM	P-values		
	HS	AS	mEmP	MEMP	MEHP	HEMP	HEHP		B	D	B × D
Flavor	6.29[a]	5.72[b]	5.19[c]	5.96[b]	6.31[ab]	6.55[a]	6.01[b]	0.03	**	**	NS
Juiciness	6.43[a]	5.43[b]	5. 28[d]	5.64[c]	6.18[b]	6.51[a]	5.72[c]	0.05	**	**	**
Tenderness	6.57[a]	5.56[b]	5.35[d]	5.70[c]	6.16[b]	6.56[a]	5.75[c]	0.04	**	**	*
Overall acceptability	6.58[a]	5.57[b]	5.27[d]	5.73[c]	6.12[b]	6.54[a]	5.84[c]	0.03	**	**	*

HS: Hararghe highland lambs; AS: Afar lambs; mEmP: minimum energy and minimum protein; MEMP: medium energy and medium protein; MEHP: medium energy and high protein; HEMP: high energy and medium protein and HEHP: high energy and high protein.
B × D: interaction between breed and diets.
* (P<0.05) and ** (P<0.01).
SEM: standard error of the means.
NS: non significant.

Table 7 Correlation coefficients[1] of meat sensory evaluation for Hararghe and Afar lambs

HS (upper diagonal) AS (lower diagonal)	Flavor	Juiciness	Tenderness	Overall acceptability
Flavor	-	0.90***	0.84***	0.95***
Juiciness	0.52*	-	0.86***	0.96***
Tenderness	0.72**	0.84***	-	0.94***
Over all acceptability	0.85***	0.88***	0.95***	-

HS: Hararghe highland lambs and AS: Afar lambs.
* (P<0.05); ** (P<0.01) and *** (P<0.001).

Likewise, the overall acceptability of meat from Hararghe and Afar rams had a strong (P<0.001) direct correlation with flavor, juiciness, and tenderness. However, the juiciness panelists' taste had strong (P<0.001) direct relationship with flavor taste from Hararghe rams' meat while they had medium correlation in meat taste from Afar rams. In agreement with the results reported by Ekiz *et al*. (2012), there was a positive and significant correlation between flavor intensity and overall acceptability. Besides, most previous studies indicated that juiciness had shown a closer correlation with fat content than water holding parameters (Muela *et al*. 2010). Likewise, tenderness and juiciness are closely related i.e., the more tender the meat, the more quickly the juices are released by chewing, and the juicier the meat appears.

CONCLUSION

The findings from this study have indicated that Hararghe rams' meat had higher fat composition, WHC, L*, b* color index values, and more tenderness meat than Afar rams' meat. The MEHP and HEMP diets were appropriate diet in promoting better meat quality parameters in Hrarghe and Afar rams. The MEMP diet was optimum diet resulting in a desirable eating and meat quality characteristics. Even though there were significant effects of breed and diet composition on most of the meat quality parameters, both Hararghe and Afar rams' meat in all treatments were in the acceptable standard ranges recommended for meat quality parameters (pH of 24 hr., WB shear forces, WHC). Returning to the question posed at the beginning of this study, it is now possible to state that dark cutting meat observed after slaughtering of free-grazing animals originated from highland areas like Haraghe Highland sheep has been improved by proper ration formulation and management.

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