Comparative Evaluation of Proximate Chemical Composition and Eating Quality of Meat from Three Selected Ethiopian Sheep Breeds in Different Levels of Concentrate Supplement

Shashie Ayele[1]*, Mengistu Urge[2], Getachew Animut[3], and Mohammed Y. Kurtu[2]

[1]Department of Animal Sciences, Debre-Markos University, P. O. Box 269, Debremarkos, Ethiopia
[2]School of Animal and Range Sciences, Haramaya University, P. O. Box 138, Dire Dawa, Ethiopia
[3]Agricultural Transformation Agency, P. O. Box 708, Addis Ababa, Ethiopia

Abstract: An experiment was conducted to assess the influence of sheep breed and concentrate supplement level on proximate chemical composition and eating quality of mutton. At the end of 90 days fattening, all sheep were slaughtered and 6 to 13 rib position of *longissimus lumborum (LL)* muscle was sampled for meat quality assessments. Higher a* (15.5±0.12), b* (12.9±0.15), and ultimate pH (5.8±0.03) values were recorded in LL muscle of Washera breed than Blackhead Ogaden (BHO) and Horro breeds. However, Washera sheep had lower L* (34.7±0.29) (*P*<0.001) than BHO sheep. Sheep consumed L2 diet produced mutton with higher intramuscular fat (IMF), lower moisture, and protein than those fed L1 diet. BHO sheep displayed lower protein and higher IMF than Horro and Washera sheep. Lower flavour and overall acceptability were recorded for BHO meat. In conclusion, the study revealed that meat of the three studied sheep breeds differ in nutritional and sensory quality attributes.

Keywords: *Colour, Fat, Flavour, Juiciness, Meat, Protein, Sheep*

Introduction

Sheep is important meat animal worldwide and its production and consumption spread across the globe. There are virtually no religious or cultural taboos towards eating of sheep meat, as a result sheep are readily available to societies in which eating beef, pork or other meat types is culturally forbidden. In some religions in addition to using lamb meat in regular diet, it is also valued and consumed for religious significance (Montossi *et al*., 2013). Sheep meat is one of the most liked and consumed meat in Ethiopia and its demand increased particular during traditional and religious festivities (Getachew and Mohamadou, 2014).

Meat consumption, as a strategic source of protein in human diet is expected to grow substantially by the year 2050 around the world. The projected demand shows that sheep meats put at the fourth position after poultry, pig, and bovine meats in that order (FAO, 2012). The rapid growth in demand for meat in the world provides a great opportunity for livestock resource-rich countries like Ethiopia. However, in recent years consumers are conscious about their health and the preference has been changing rapidly to consume quality meat. Research report indicated that 41% of consumers in the European Union countries are prepared to pay more for high quality food. Furthermore, consumers of beef have been reported to be prepared to pay as much as two to three times more for quality (Lyford *et al*., 2010).The demand for quality meat by the consumers is an alarm for producers to focus on quality meat production in addition to increasing the volume of the product. Meat quality is defined by those traits the consumer perceives as desirable, which includes both nutritional and eating quality traits among others (Warner *et al*., 2010). Nutritional quality or perceived healthiness, especially in relation to the amount and type of fat (Wood *et al*., 1999; 2008) is one of the quality trait emphasized by consumers. Eating quality of meat such as tenderness, juiciness, flavor, and colour are determinant in consumers' initial and continued interest in meat consumption (Fishell *et al.,* 1985; Wheeler *et al*., 1990) both of which are influenced by nutrition and genetic factors (Muchenje *et al*., 2009; Warner *et al*., 2010).

Despite the numerical importance and diversity of sheep in Ethiopia (Galal, 1983; Solomon *et al.,* 2007), characterization for meat quantity and quality attributes of indigenous sheep breeds have been minimal. So far documented information on chemical composition, eating quality and other meat quality traits of Ethiopian sheep are very few. On the other hand, Ethiopia is competing in the world market for exporting live sheep and meat to a number of Middle East countries (ESGPIP, 2011; AGP-LMD, 2013), which necessitates the supply of quality meat to the market demands. Therefore, to be competent at international markets, the meat quality of sheep breeds of the country should be evaluated and compared among breeds. This information should be made available for consumers to make an informed decision in purchasing meat and for producers and breeders to design management and breeding strategy for appropriate sheep improvement program in the country. The objective of the present study was, therefore, to evaluate chemical composition and eating quality of meat from three selected Ethiopian sheep breeds (Blackhead Ogaden (BHO), Horro, and Washera) with two levels of concentrate supplement.

*Corresponding Author. E-mail: aklileshashie@gmail.com

Published by Haramaya University, 2018

ISSN: 2616-8804 (Print)

Materials and Methods

Study Site

The study was conducted at goat farm of Haramaya University, Ethiopia, which is located at 9°25' N latitude and 42° 2' E longitude. The area lies at an altitude of 1950 meters above sea level and receives 790 mm total average annual rainfall of bimodal type (Mishra *et al.,* 2004). It has an average temperature of 16ºC with mean maximum and minimum annual temperatures of 24.02 and 9.73 ºC, respectively.

Animal Management and Experimental Design

All animal handling practices followed the international guiding principles listed by the Council for International Organizations of Medical Sciences and the International Council for Laboratory Animal Science (2012).Three sheep breeds, BHO, Horro, and Washera, 16 animals from each breed were purchased from local markets where each breed is found and transported to Haramaya University to be used for the experiment. The animals were male, intact and yearling with similar body condition and having initial body weight of 21.3±1.5 kg (mean ± SD). Age of the animals was determined by their dentition and information obtained from the owners. Animals were ear tagged for identification and quarantined for 21 days. During this time, they were vaccinated for ovine pasteurellosis (2ml/sheep), injected with Ivermectin (l ml/sheep) and de-wormed with Albendazole (300mg) against endo-parasites, and sprayed with Diazinine (1 ml/liter of water) for ecto-parasites. At the end of the quarantine, each sheep was weighed and placed in an individual pen with 134.8 × 78 cm dimension equipped with feed troughs and water buckets.

The experiment was arranged in a 2 x 3 (2 concentrate levels and 3 breeds) in a factorial treatment arrangement in a completely randomized block design. Sheep from each genotype were blocked in to eight blocks of two animals from each breed (total six sheep in a block) based on their initial body weight. In each block the two CSL were randomly assigned within a breed. The two CSL were 1% and 1.75% of body weight of each sheep, designated as L1 and L2, respectively and was provided into two equal proportions at 0800 and 1600 hours. The concentrate comprised of wheat bran (44%), noug seed cake (29%), maize grain (26%) and salt (1%) on DM basis, and the chemical composition of the feeds used is shown in Table 1. Natural pasture hay was used as a basal diet. It was provided chopped and *ad libitum* with about 20% refusal rate. Clean water was available to the animals all times throughout the experiment. At the end of the feeding experiment, all sheep were slaughtered at Haramaya University slaughterhouse by severing the jugular vein and the carotid arteries.

Ultimate pH and Meat Colour Determination

At 24 hour postmortem, ultimate pH (pHu) was measured using penetrating glass electrode of a portable pH-meter (meat pH meter-HI99163, HANAN instrument) from the *longissimus lumborum (LL)* muscle at 12-13th rip position. The probe was calibrated with pH 4 and 7 standard buffer solutions. Before and after each reading, the electrode pointer was thoroughly cleaned with distilled water and cotton towel. Measurements were made in triplicate for each animal and the mean was used for analysis.

At the end of pH measurement, meat samples were taken from 6 to 13 rip positions of LL muscles from left and right side carcass of all sheep. The cut meat samples, after trimming the external fat, were exposed to air for 30 minutes for colour estimation. Colour was determined by the three fundamental colour coordinates L*, a*, and b*. The L* measures lightness and is a measure of light reflected (100 = white; 0 = black); a* measures positive red, negative green and b* measures positive yellow, negative blue (Muchenje *et al.*, 2009). Measurements were taken from three locations of individual steaks using digital colour meter (Mini scanEZ-MSEZ147, Hunter Lab) and the mean was used for analysis. The machine was calibrated before and after taking measurements using the black and white standard colour samples provided for this purpose. Then after, samples taken from left and right side of the carcass were vacuum-packed separately using a vacuum packing machine (Food saver model V2860-1BAGSEALER, P.R.C.) in oxygen-impermeable film to avoid desiccation and oxidation, and kept in a refrigerator at -20 ºC until used for subsequent quality determination (AMSA, 2015).

Proximate Chemical Analysis

Pre-weighted muscles from the left sides were dried at 55^{o}C for 72 hours for ease of grinding. After recording partial dry matter (PDM), the meat samples were grind to pass 1 mm sieve screen and stored in air tight plastic bags and put at 4 ^{o}C pending chemical analysis. From partially dried ground samples, 3 g was weighed into a pre-weighed crucible dish and then dried overnight at 105°C in a forced draft oven for determination of dry matter. Then the moisture content was determined by subtracting hundred from the dry matter. Ash was determined by burning the samples dried during moisture determination by incinerating in a muffle furnace at 600^{o}C for 12 h, cooled in desiccators and the incinerated sample (ash) weighed and the ash content was expressed as percentage of the weight of ash to weight of dried sample. Nitrogen (N) was analyzed by Kjeldahl method (AOAC, 1990) and CP was determined as N x 6.25. Crude fat was extracted using Soxhlet apparatus where a 2 g sample was extracted repeatedly for 6 hour by reflux with diethyl ether (boiling point of 34.5^{o}C). After all the solvent evaporated, the weight of the flask along with the extracted oil was recorded. Crude fat content was calculated using the following formula and all analyses were run in duplicates.

$$\text{Crude fat (\%)} = \frac{\text{Flask weight after extraction} - \text{Flask weight before extraction}}{\text{Sample weight}} * 100$$

Eating Quality

The frozen muscles from the right sides were thawed at 4 °C for 12 hours before being used. The samples were coded, wrapped individually in aluminum foil and roasted in pre-heated oven (for 15 minutes) at 125 °C for 45 minutes (Griffin *et al.,* 1985). The cooked samples were cut into equal pieces by one person to make as uniform in size and shape as possible and wrapped again with the same aluminum foil and placed in a heater to keep it warm.

Ten panelists (8 males and 2 females, 29-37 years old) from Haramaya University Food Science and Post-harvest Technology Department staff were trained in the assessment procedure one day before the evaluation started. The panelists were served one sample at a time and asked to rate each sample. Water was served to the panelists to rinse their mouths after scoring each sample to minimize flavour carryover. The evaluators scored each sample on a nine point hedonic scale for flavor (like to dislike), tenderness (tender to tough), juiciness (juicy to dry), and overall acceptability (like to dislike). For flavour and overall acceptability (9 = like extremely, 8 = like very much, 7 = like moderately, 6 = like slightly, 5 = neither like or dislike, 4 = dislike slightly, 3 = dislike moderately, 2 =dislike very much and 1 = dislike extremely. For tenderness: 9 = extremely tender, 8 = very much tender, 7 = moderately tender, 6 = slightly tender, 5 = neither tender nor tough, 4 = slightly tough, 3 = moderately tough, 2 = very much tough, 1 = extremely tough. For juiciness: 9 = extremely juicy, 8 = very much juicy, 7 = moderately juicy, 6 =slightly juicy, 5 = neither juicy nor dry, 4 = slightly dry, 3 = moderately dry, 2 =very much dry, 1 = extremely dry. Scores from 6 to 9 are considered acceptable (AMSA, 2015). The evaluation was completed within a day.

Statistical Analysis

Data were analyzed using General Linear Model procedures of SAS (SAS, 2008) according to a 2 x 3 factorial arrangement with breed and diet as main effects in a Completely Randomized Block Design. Least squares means were separated by PROC GLM with the PDIFF option of SAS for treatments with significant effect at $P<0.05$ by employing Tukey's multiple comparison procedure. Since breed by diet interaction effect was not significant for all parameters, least squares means with accompanying standard error of main effects were presented and discussed.

Results

Proximate Chemical Composition

Average daily gain (ADG), cold carcass weight (CCW), protein, fat, and moisture contents were affected by breed and CSL (Table 2). The greatest ($P<0.0001$) ADG and CCW were recorded in Horro breed. Higher ($P<0.0001$) intramuscular fat (IMF) and lower moisture contents were recorded from BHO sheep meat than the meat obtained from Horro and Washera sheep. Meat protein ranked Horro>Washera>BHO ($P<0.0001$). The effect of breed on meat ash was not significant ($P>0.05$). The ADG, CCW, IMF, and ash concentration were higher, but moisture and protein concentration were lower for the group supplemented with L2 than L1 ($P<0.0001$).

Table 1. Experimental diets and their chemical composition (% for DM and % DM for others)

Diets	DM	OM	CP	NDF	ADF
Hay	89.7	92.7	7.9	79.4	50.2
Concentrate mix	88.8	94.5	19.2	39.9	12.8
Maize grain	86.9	98.6	8.4	29	4.2
Wheat bran	87.9	94.5	15.5	52.9	13.9
Noug seed cake	90.7	94.1	36.2	29.4	15.6

DM= Dry matter; OM= Organic matter; CP= Crude protein; NDF= Neutral detergent fiber; ADF= Acid detergent fiber; Concentrate mix composed of wheat bran (44%), noug seed cake (29%), maize (26%), and salt (1%).

Table 2. Chemical composition of the *longissimus lumborum* muscle from three Ethiopian fat tailed hair sheep breeds supplemented with two levels of concentrate

Traits	Sheep Breeds (B)				CSL			*P*- value		
	BHO	H	W	SEM	L1	L2	SEM	CSL	B	CSL x B
ADG (g/d)	49.2^b	59.8^a	43.3^c	1.19	44.2^b	57.3^a	0.98	<.0001	<.0001	0.3903
CCW (kg)	9.5^c	11.5^a	10.1^b	0.11	10^b	10.7^a	0.09	<.0001	<.0001	0.2568
Protein (% DM)	20.7^c	21.9^a	21.1^b	0.14	21.5^a	21^b	0.11	0.023	<.0001	0.5468
Fat (% DM)	10.9^a	9.8^b	9.9^b	0.16	9.2^b	11.2^a	0.13	<.0001	<.0001	0.6059
Ash (% DM)	5.5	5.6	5.5	0.05	5.4^b	5.6^a	0.04	0.0322	0.5664	0.4715
Moisture (%)	72.1^b	73.5^a	73.8^a	0.20	74^a	72.3^b	0.16	<.0001	<.0001	0.09766

^{a,b,c} Within genotype and CSL in the same row, means with different superscript letter differ significantly (P<0.05); BHO= Blackhead Ogaden; H= Horro; W= Washera; L1= Hay + 1% of body weight C; L2= Hay +1.75% of body weight C; C= Concentrate; CSL= Concentrate supplement level; SEM = Standard error of mean; CCW= Cold carcass weight; ADG= Average daily gain; Moisture (%)= 100 - Meat dry matter.

Meat Color and Ultimate pH

The effect of CSL was not significant (*P*>0.05) on color coordinates (L*, a*, b*) and ultimate pH indicating glycogen reserve was enough at both supplements level for postmortem glycolysis. However, the effect of breed was significant (*P*<0.05) on both parameters (Table 3). The meat obtained from BHO sheep was lighter (L*) (*P*<0.001) than the meat obtained from the two breeds. The higher (*P*<0.001) redness (a*) and ultimate pH values were recorded in meat of Washera sheep as compared to the other two breeds. The yellowness (b*) of Washera sheep meat was greater (*P*<0.05) than Horro, while the value for BHO was similar (*P*>0.05) with the two genotypes.

Eating Quality

Breed has significant (*P*<0.0001) effect on all the eating quality traits (Table 4), while dietary effects were statistically similar for flavor and overall acceptability scores, but diet effect varied in meat tenderness and juiciness parameters. The most tender, more desirable flavour, and more over all acceptable meat by sensory panel was obtained from Horro sheep indicating meat from Horro breed is more preferred than the rest of the breeds. However, Juiciness score was lower (*P*<0.0001) than BHO but similar to Washera breed. The meat obtained from L2 supplemented sheep was juicier and tender than those consumed L1 supplement. On the other hand, the effect of CSL was not apparent on meat flavor and overall acceptability scores.

Table 3. Color and ultimate pH of the *longissimus lumborum* muscle from three Ethiopian fat tailed hair sheep breeds supplemented with two concentrate levels

Variables	Sheep Breeds (B)				CSL			*P- value*		
	BHO	H	W	SEM	L1	L2	SEM	CSL	B	CSL x B
L*	36.6^{a}	35.1^{b}	34.7^{b}	0.29	35.2	35.7	0.24	0.1406	0.0002	0.151
a*	14.8^{b}	14.8^{b}	15.5^{a}	0.12	14.9	15.1	0.09	0.2218	0.0002	0.0774
b*	12.7^{ab}	12.3^{b}	12.9^{a}	0.15	12.6	12.6	0.12	0.8057	0.0355	0.094
pH(ult)	5.7^{b}	5.7^{b}	5.8^{a}	0.03	5.76	5.77	0.02	0.8306	0.0327	0.8417

[a, b] Within genotype and CSL in the same row, means with different superscript letter differ significantly (P<0.05); BHO= Blackhead Ogaden; H= Horro; W= Washera; L1 = Hay + 1% of body weight C; L2= Hay +1.75% of body weight C; C= Concentrate; CSL= Concentrate supplement level; SEM= Standard error of mean; pH (ult)= pH after 24 hours postmortem. L, a*, and b* are color coordinates and measures light, red, and yellow colors, respectively.*

Table 4. Eating quality parameters of the *longissimus lumborum* muscle from three Ethiopian fat tailed hair sheep breeds supplemented with two levels of concentrate

Parameters	Sheep Breeds (B)				CSL			*P*- value		
	BHO	H	W	SEM	L1	L2	SEM	CSL	B	CSL x B
Tenderness	6.8^{b}	7.2^{a}	6.5^{c}	0.06	6.6^{b}	7.1^{a}	0.05	<.0001	<.0001	0.5103
Juiciness	6.7^{a}	6.4^{b}	6.3^{b}	0.05	6.2^{b}	6.7^{a}	0.04	<.0001	<.0001	0.5103
Flavor	6.5^{c}	6.9^{a}	6.7^{b}	0.05	6.74	6.78	0.04	0.4512	<.0001	0.4938
Overall acceptability	6.5^{c}	7.1^{a}	6.8^{b}	0.04	6.8	6.78	0.03	0.3872	<.0001	0.0901

[a,b,c]Within genotype and CSL in the same row, means with different superscript letter differ significantly (P<0.05); BHO= Blackhead Ogaden; H= Horro; W= Washera; L1= hay + 1% of body weight C; L2= Hay +1.75% of body weight C; C = Concentrate composed of wheat bran (44%), noug seed cake (29%), maize (26%), and salt (1%); CSL= Concentrate supplement level; SEM= Standard error of mean.

Discussion

Proximate Quality

Variation in chemical fat concentration among breeds in the present study may reflect variation in physiological maturity, which in turn affect conversion of dietary energy into fatty tissue (Lawrie and Ledward, 2006).This may be attributed to the fact that genotypes alter the activity of lipogenic enzymes in sheep muscle such as Δ-desaturase and can influence the amount and composition of deposited fatty acid (Vacca *et al*., 2008). Intramuscular fat accretion is heritable and its heritability is estimated at 0.48 (Mortimer *et al*., 2014). The presence of variation in chemical fat among different breeds of sheep has been reported earlier by Komprda *et al.* (2012) and Barkawi *et al.* (2009). On the other hand, the higher IMF recorded from meat of L2 supplemented sheep than from L1 could be associated to increased concentrate intake from the higher offer that enhance the production of higher levels of propionate from ruminal fermentation and/or higher glucose absorption in the small intestine from non-degradable starch (Schoonmaker *et al*., 2010). This would, in turn, promote insulin production thereby stimulate lipogenesis (Schoonmaker *et al.,* 2003). The IMF values obtained for the present sheep breeds is lower than that of 11.13 to 15.01% reported from *longissimus dorssi* muscle of Iranian lambs in various fat tail and carcass weight classes (Abbas *et al*., 2013) but was within the range of 5.4 to 11.5% chemical fat reported for castrated red Massi sheep (Safari *et al*., 2011). It is noted in a number of literature that intramuscular fat content is a key determinant of eating quality parameters such as flavour, juiciness, tenderness, and visual characteristics of meat (Hopkins *et al*., 2006; Pethick *et al*., 2007; Muchenje *et al*., 2009;

Jacob and Pethick, 2014). Hopkins *et al.* (2006) reported minimum requirement for ether extractable fat to be 5% in order to achieve acceptable consumer satisfaction for lamb 'red meat' cuts used for grilling. The lower meat moisture recorded from BHO breed meat than the rest of the breed as well as meat from L2 fed sheep in the present study was due to the higher IMF contents as the two are inversely related (Tshabalala *et al.,* 2003).

The differences in meat protein value among breeds might reflect variation in lean tissue development due to variation in stage of physiological maturity. Lean meat is mainly composed of muscle fibers and muscle proteins are the components of it (Lawrie and Ledward, 2006). The higher protein in meat of L1 concentrate fed sheep could be due to lower dietary energy intake as a result lean tissue is developed instead of fatty tissue. Lean and fat tissue requires different amounts of energy to lay down (Warriss, 2000). In line with the present study, Safari *et al.* (2011) reported higher protein content in meat of low energy supplemented red Massi sheep than from the higher concentrate group. The ash content recorded in the present study is within the range of 4.08 to 6.15% reported for Iranian lambs (Abbas *et al*., 2013) and 4.7-5.8% for red Massi sheep (Safari *et al.,* 2011). The similar ash content among breeds of sheep in the present study might be associated with age similarity.

Color and Meat pH

Meat color is considered as important factor affecting consumer acceptance, purchasing decisions, and satisfaction of meat products as it is visual measure of freshness and quality (Muchenje *et al*., 2009; Dorgival *et al*., 2016). The reason for variation in luminosity (L*) between BHO and the other two breeds could be due to the higher IMF content in meat of BHO breed. Baublits *et al.* (2004) reported that higher levels of IMF increase meat brightness. Similarly, the review work of Muir *et al.* (1998) indicated that increased luminosity is associated with increased marbling scores in grain-fed cattle. Likewise, meat from L2 fed group tended to have higher magnitude of bright color than L1 due to higher IMF in L2 fed sheep meat. The differences in redness (a*) of meat among breeds may be due to variation in myoglobin concentration (Muchenje *et al.,* 2009). Although meat myoglobin content was not assessed in the current study, literatures show that its content is influenced by breed (Dorgival *et al.,* 2016). Myoglobin is the major pigment in meat, accounting for 50 to 80% of the total pigment or meat color (Kerry *et al.,* 2002), which justifies the variation among the present breed in this parameter. Yellowness (b*) differences in sheep genotype observed in the present study appears to be in line with significant variation noted between Texel lambs, and Dorper and Charollais (Partida *et al.,* 2012).

Meat color variables for the three breeds are above the acceptable threshold values for lightness (34 (L*)) and redness (9.5 (a*)) values established by consumer evaluations of fresh lamb meat (Khliji *et al*., 2010). The average values reported for L* and a* were lower, the b* value was higher than those reported by Souza *et al.* (2016) and Santos-siliva *et al.* (2002) for various sheep breeds. The lower L* and a* values as compared to the two studies might be due to higher yellowness value recorded in the present study and due to age and breed variation of the animals in the various studies. Muchenje *et al.* (2009) in their review article noted that the darker lean (low L*) values may be attributed to increased myoglobin, decreased muscle glycogen, or both, and the yellow fat.

The muscle of a living animal has a pH of 7.1. Good quality meat usually has a pH of 5.4–5.7 (Lawrie and Ledward, 2006).The extent to which pH is lowered after slaughter depends on the amount of glycogen in the muscle prior to the animal's death. The average ultimate pH of 5.77 for all sheep after completion of glycolysis (24 hour postmortem) in the present study is within the quality range. Lack of dietary effect on pH values, indicates the two CSL could provide sufficient pre-slaughter muscle glycogen reserve that has similar potential for pH decline in muscles postmortem. These results are in agreement with the observation made for Corriedale and Texel ×Corriedale (Carmen *et al*., 2014) fed increasing levels of whole rice meal supplement to straw based diets. However, Olfaz *et al.* (2005) recorded meat pH difference in Karayaka growing rams fed high energy diets compared with lambs on low energy diet. The breed effect on meat pH in the present study might be attributed to variation in muscle glycogen reserve at slaughter which is inversely related to the ultimate pH. Similar to the present study significant breed effect was reported between Santa Ines sheep and its cross with Dorper (Souza *et al.,* 2016).

Eating Quality

Tenderness can be attributed to a person's perception of meat such as softness to tongue, less resistance to tooth pressure and adhesion (Muir *et al.,* 1998; Ford *et al*., 2012). In the present study, significantly higher tenderness score given for meat from L2 supplemented sheep was because of greater IMF content (Savell and Cross, 1988). According to the authors, fat is lower in density than heat-denatured protein in cooked meat, and as the fat percentage increases, the overall density of the meat decreases. Therefore, as bulk density decreases within a given bite of meat, the meat seems tenderer. The authors further explained that IMF is mainly triglycerides stored in adipose cells of the muscle and when meat is cooked, triglycerides melt and bathe the muscle fibers. As the meat is chewed, the muscle fibers slide more easily resulting in an increased perception of tenderness. However, the causes of tenderness variation are extremely complex and not fully understood. Breed, nutrition, carcass weight, and rate of growth are also some of the factors that attribute to tenderness variation (Muir *et al*., 1998; Thompson *et al.,* 2006; Muchenje *et al*., 2009).The influence of genotype on tenderness variation can be due to variations in glycolytic rate driven through differences in muscle fiber type among genotypes (Thompson *et al*., 2006). Some breeds have a finer muscle grain related to the macroscopically visible muscle fiber bundles which is favored by consumers (Albrecht *et al*., 2006). In the present study the highest tenderness score given for Horro meat despite significantly lower IMF might be related to breed, carcass weight, and rate of growth. The influence of breed on sheep meat tenderness and other eating quality attributes have been reported by many researchers (Arsenos *et al.,* 2002; Teixeira *et al*., 2005; Ekiza *et al*., 2009).

The improvement in juiciness as IMF increases for BHO meat as well as meat from L2 supplemented sheep supports the hypothesis that during initial chewing, fat is released which stimulates secretion of salivary glands. Fat is softer than muscle, and lubricates muscle fibres and make people to perceive the meat is juicier and tenderer. Fat provides protection against the negative effects of over-cooking or high heat on protein denaturation. Meat proteins are involved in binding water in the muscle fiber. Water-holding capacity is a factor that determines the juiciness of meat (Muchenje *et al.,* 2009). As meat is cooked, proteins denature and lose some of their ability to bind water. Fat can act to insulate the transfer of heat or slow down the heat transfer so that protein denaturation is less severe and less moisture is lost during cooking and consequently, juiciness improve (Savell and Cross, 1988; Warriss, 2000).

Flavor is one of the most important sensory attributes for the overall acceptance of sheep meat (Wood *et al.,* 2003; Warner *et al.,* 2010). Ping *et al.* (2008) reported that the degree of marbling of the muscle is significantly related to flavor intensity, and meat with a desirable flavor tended to have higher levels of IMF and more intense marbling. The flavor of mutton in particular has been attributed to the carbonyl, or other polar compounds found in sheep fat (Channon *et al*., 2003). Sulphur compounds and branched chain fatty acids are also responsible for sheep meat flavor. In the present study, breeds difference in sensory panel scoring for flavor might be related to variation in flavor providing compounds in their meat. In line to the present study, Young *et al.* (1993) and Fisher *et al.* (2000) observed significant flavor difference in sheep breeds. On the other hand, lack of significant variation between concentrate supplement levels for flavor could be due to the fact that differences in CSL were not large enough to elicit significant effect in flavor forming precursors and in turn flavor change. Generally the eating quality scores given by the sensory panelist for all breeds fall within the acceptable range set by AMSA (2015).

Conclusion

The present sheep breeds produced meat with medium to high fat content. This allows the choice of breed to satisfy the various consumer preferences and market niche. Furthermore, variation exists among the breeds in meat sensory quality attributes. Accordingly, the most tender, more desirable flavor, and more over all acceptable meat by sensory panel was obtained from Horro sheep indicating meat from Horro breed is most preferred compared to Blackhead Ogaden and Washera sheep breeds, but the sensory scores for all breeds fall within the acceptable range. Nevertheless, meat from BHO sheep have lowest score for flavor and overall acceptability but had highest IMF content compared with Horro and Washera breeds meat. Supplementing concentrate at the rate of 1 and 1.75% body weight provided meat with acceptable fat content, meat color, pH, and overall acceptable sensory traits.

Acknowledgements

The authors would like to thank Haramaya University for providing financial support and allowing the use of research facilities. The first author acknowledges Debremarkos University for providing paid study leave and supplementary research fund.

Conflict of Interests

The authors declare that they have no competing interests.

References

Abbas, A., Ahmad, Z. S., Ali, R. Y., Maryam, H. O. & Anna, W. C. (2013). Determining the Effect of The Fat Tail and Carcass Weight on Meat Fatty Acid Composition of Iranian Lambs. *Small Ruminant Research,* 115: 34–39.

AGP-LMD (Agricultural Growth Project-Livestock Market Development) (2013). Livestock Market Development Value Chain Analysis for Ethiopia: Meat and Live Animals, Hides, Skins, Leather and Dairy, Expanding livestock markets for the small-holder producers.

Albrecht, E., Teuscher, F., Ender, K. & Wegner, J. (2006). Growth-and Breed-Related Changes of Muscle Bundle Structure in Cattle. *Journal of Animal Science,* 84: 2959-2964.

AMSA (American Meat Science Association) (2015). Research guidelines for Cookery, Sensory Evaluation, and Instrumental Tenderness Measurements of Meat, 2nd ed., Champaign, Illinois, USA, p: 104.

AOAC (Association of official analytical chemists) (1990). Official Methods of Analysis, 15th ed., Virginia, USA.

Arsenos, G., Banos, G., Fortomaris, P., Katsaounis, N., Stamataris, C., Tsaras, L. & Zygoyiannis, D. (2002). Eating Quality of Lamb Meat: Effects of Breed, Sex, Degree of Maturity and Nutritional Management. *Meat Science,* 60: 379-387.

Barkawi, A. H., El-Asheeri, A. K., Hafez, Y. M., Ibrahim, M. A. & Ali, M. M. (2009). Growth and Carcass Characteristics of Lambs In Relation To Plasma IGF-I and Some Histological Traits of

Longissimus Lumbarum and *Biceps Femoris* as Affected by Breed and Age at slaughter. *Livestock Science,* 124: 9-14.

Baublits, R. T., Brown, A. H., Pohlman, F. W., Johnson, Z. B., Onks, D. O. & Loveday, H. D. (2004). Carcass and Beef Colour Characteristics of Three Biological Types of Cattle Grazing Cool Season Forages Supplemented With Soyhulls. *Meat Science,* 68: 297-303.

Carmen, L. de S. R., José, L. R., Vivian, F., Mabel, M. W., Heden Luiz, M. M., Maria, T. M. O. & Frank, S. (2014). Body Development, Carcass, and Meat Quality of Confined Lambs Fed Increasing Levels of Whole Rice Meal. *Tropical Animal Health Production,* 46: 191–195.

Channon, H. A., Lyons, R. & Bruce, H. (2003). Sheep Meat Flavour and Odour: A Review Report Prepared for the Sheep CRC, CSIRO Livestock Industries, St. Lucia, QLD, Food Science, Australia, Brisbane, p: 69.

Council for International Organizations of Medical Sciences and the International Council for Laboratory Animal Science. (2012). International Guiding Principles for Biomedical Research Involving Animals.

Dorgival, M. de L. J., Francisco, F. R. de C., Felipe, J. S. da S., Adriano, H. do N. R., Luciano, P. N. & Gelson, dos S. D. (2016). Intrinsic Factors Affecting Sheep Meat Quality. *Revista Colombiana de Ciencias Pecuarias,* 29: 3-15.

Ekiza, B., Yilmaz, A., Ozcan, M., Kaptan, C., Hanoglu, H. & Erdogan, I. (2009). Merino, Ramlic, Kivircik, Chios and Imroz Lambs Raised under an Intensive Production System. *Meat Science,* 82: 64-70.

ESGPIP (Ethiopia sheep and goat productivity improvement program) (2011). Export Requirements For Meat and Live Small Ruminants: How Can Development Agents Assist Producers To Improve Small Ruminant Export? *Technical Bulletin,* No.47.

FAO (Food and Agriculture Organization) (2012). OECD-FAO Agricultural Outlook 2012-2021. Food and Agriculture Organization of the United Nations.

Fishell, V. K., Aberle, E. D., Judge, M. D. & Perry, T. W. (1985). Palatability and Muscle Properties of Beef as Influenced By Pre-Slaughter Growth Rate. *Journal of Animal Sci*ence, 61: 151-157.

Fisher, A. V., Enser, M., Richardson, J. R., Wood, I. D., Nute, G. R. & Kurt, E. (2000). Fatty Acid Composition and Eating Quality of Lamb Types Derived from Four Diverse Breed x Production Systems. *Meat Science,* 55: 141-147.

Ford, L., Matthews, K., Hadley, P., Homer, D. & Drewett, M. (2012). A glossary of carcass and meat quality terms, Agriculture and Horticulture Development Board, Warwickshire, UK.

Galal, E. S. E. (1983). Sheep Germ Plasm in Ethiopia. *Animal-Genetic-Resources-Information,* 1: 4-12.

Getachew Legese & Mohamadou Fadiga (2014). Small Ruminant Value Chain Development In Ethiopia: Situation Analysis and Trends. ICARDA/ILRI PROJECT REPORT.

Griffin, C. L., Savell, J. W., Smith, G. C., Rhee, K. S. & Johnson, H. K. (1985). Cooking Time, Cooking Losses and Energy for Cooking Lamb Roasts. *Journal of Food Quality,* 8 (2): 69.

Hopkins, D. L., Hegarty, R. S., Walker, P. J. & Pethick, D. W. (2006). Relationship Between Animal Age, Intramuscular Fat, Cooking Loss, pH, Shear Force and Eating Quality of Aged Meat from Sheep. *Australian Journal of Experimental Agriculture,* 46: 879-884.

Jacob, R. H. & Pethick, D. W. (2014). Animal Factors Affecting the Meat Quality of Australian Lamb Meat. *Meat Science,* 96: 1120-1123.

Kerry, J., Kerry, J. & Ledward, D. (2002).´Meat Processing Improving Quality, CRC press Boca Raton Boston New York Washington, DC.

Khliji, S., Van de Ven, R., Lamb, T. A., Lanza, M. & Hopkins, D. L. (2010). Relationship Between Consumer Ranking of Lamb Colour and Objective Measures of Colour. *Meat Science,* 85: 224-229.

Komprda, T., Kuchtík, J., Jarošová, A., Dračková, E., Zemánek, L. & Filipčík, B.(2012). Meat Quality Characteristics of Lambs of Three Organically Raised Breeds. *Meat Science,* 91: 499-505.

Lawrie, R. A. & Ledward, D. A. (2006). Lawrie's Meat Science, 7th ed., Woodhead Publishing Limited Ltd., Abington, UK, p: 442.

Lyford, C., Thompson, J. M., Polkinghorne, R., Miller, M., Nishimura, T., Neath, K. & Belasco, E. (2010). Is Willingness to Pay (WTP) For Beef Quality Grades Affected by Consumer Demographics and Meat Consumption Preferences? *Australasian Agribusiness Review,* 18: 1-17.

Mishra, B. B., Heluf Gebrekidan, Kibebew Kibret, Mohammed Assen & Bruk, E. (2004). Soil and Land Resource Inventory at the Alemaya University Research Farm with Reference to Land Evaluation for Sustainable Agricultural Management and Production. *Soil Sciences Bulletin* No. 1, Haramaya University, Ethiopia.

Montossi, F., Font-i-Furnols, M., del Campo, M., San Julián, R., Brito, G. & Sañudo, C. (2013). Sustainable Sheep Production and Consumer Preference Trends: Compatibilities, Contradictions, and Unresolved Dilemmas. *Meat Science,* 95: 772-789.

Mortimer, S. I., van der Werf, J. H. J., Jacob, R. H., Hopkins, D. L., Pannier, L., Pearce, K. L., Gardner, G. E., Warner, R. D., Geesink, G. H., Hocking Edwards, J. E., Ponnampalam, E. N., Ball, A. J., Gilmour, A. R., Pethick, D. W. (2014). Genetic parameters for meat quality traits of Australian lamb meat. *Meat Science*, 96 (2014): 1016-1024.

Muchenje, V., Dzama, K., Chimonyo, M., Strydom, P. E., Hugo, A. & Raats, J. G. (2009). Some biochemical aspects pertaining to beef eating quality and consumer health: A review. *Food Chemistry*, 112: 279-289.

Muir, P. D., Deaker, J. M. & Bown, M. D. (1998). Effects of Forage and Grain-Based Feeding Systems on Beef Quality. *New Zealand Journal of Agricultural Research,* 41 (4): 623-635.

Olfaz, M., Ocak, N., Erener, G., Cam, M. A. & Garipoglu, A. V. (2005). Growth, Carcass and Meat Characteristics of Karayaka Growing Rams Fed Sugar Beet Pulp, Partially Substituting for Grass Hay as Forage. *Meat Science,* 70: 7-14.

Partida, J. A., Vazquez, E., Rubio, M. S. & Mendez, D. (2012). Effect of Breed of Sire on Carcass Traits and Meat Quality of Katahdin Lambs. *Journal of Food Research,* 1: 141-149.

Pethick, D. W., Barendse, W., Hocquette, J. F., Thompson, J. M. & Wang, Y. H. (2007). Regulation of Marbling and Body Composition Growth and Development, Gene Markers and Nutritional Biochemistry. In: I. Ortigues-Marty, N. Miraux & W. Brand-Williams (Eds.), Energy and Protein Metabolism and Nutrition, Wageningen Academic Publishers, the Netherlands, pp: 75-88.

Ping, L., Defa, L., Jingdong, Y., Liying, Z. & Zongyi, W. (2008). Flavour Differences of Cooked *Longissimus* Muscle from Chinese Indigenous Pig Breeds and Hybrid Pig Breed (Duroc × Landrace × Large White). *Food Chemistry,* 107 (4): 1529-1537.

Safari, J. G., Daniel, E. M., Louis, A. M., George, C. K. & Lars, O. E. (2011). Growth, Carcass Yield and Meat Quality Attributes of Red Maasai Sheep Fed Wheat Straw-Based Diets. *Tropical Animal Health Production,* 43: 89-97.

Santos-Silva, J., Mendes, I. A. & Bessa, R. J. B. (2002). The Effect of Genotype, Feeding System and Slaughter Weight on the Quality of Light Lambs: 1. Growth, Carcass Composition and Meat Quality. *Livestock Production Science,* 76: 17-25.

SAS (Statistical analysis system) (2008). SAS/STAT Users Guide, Version 9.1.' SAS Institute Inc., Cary, NC, USA.

Savell, J. W. & Cross, H. R. (1988). The role of fat in the palatability of beef, pork, and lamb. In: Designing Foods: Animal Product Options in the Market Place, National Academy Press, Washington, DC.

Schoonmaker, J. P., Cecava, M. J., Faulkner, D. B., Fluharty, F. L., Zerby, H. N. & Loerch, S. C. (2003). Effect of source of energy and rate of growth on performance, carcass characteristics of Scottish Blackface Ewes. *Animal Production,* 13: 503-509.

Schoonmaker, J. P., Trenkle, A. H. & Beitz, D. C. (2010). Effect of Feeding Wet Distillers Grains on Performance, Marbling Deposition, and Fatty Acid Content of Beef from Steers Fed Low- or High-Forage Diets. *Journal of Animal Science,* 88: 3657-3665.

Solomon Gizaw, Van Arendonk, J. A., Komen, H., Windig, J. J. & Hanotte, O. (2007). Population Structure, Genetic Variation and Morphological Diversity in Indigenous Sheep of Ethiopia. *Journal of Animal Genetics,* 38: 621-628.

Souza, D. A., Selaive-Villaroel, A. B., Pereira, E. S., Silva, E. M. C. & Oliveria, R. L. (2016). Effect of Dorper Breed on the Performance, Carcass and Meat Traits of Lambs Breed from Santa Ines Sheep. *Small ruminant research,* 145: 76-80.

Teixeira, A., Batista, S. & Delfa, R. (2005). Lamb Meat Quality of Two Breeds with Protected Origin Designation. Influence of Breed, Sex and Live Weight. *Meat Science,* 71: 530-536.

Thompson, J. M., Perry, D., Daly, B., Gardner, G. E., Johnston, D. J. & Pethick, D. W. (2006). Genetic and environmental effects on the muscle structure response post-mortem. *Meat Science,* 74 (1): 59–65.

Tshabalala, P. A., Strydom, P. E., Webb, E. C. & de Kock, H. L. (2003). Meat Quality of Designated South African Indigenous Goat and Sheep Breeds. *Meat Sciences,* 65: 563-570.

Vacca, G. M., Carcangiu, V., Dettori, M. L., Pazzola, M., Mura, M. C., Luridiana, S. & Tilloca, G. (2008). Productive Performance of Suckling Lambs. *Meat Science,* 80: 326-34.

Warner, R. D., Greenwood, P. L., Pethick, D. W. & Ferguson, D. M. (2010). Genetic and Environmental Effects on Meat Quality. *Meat Science,* 86: 171-183.

Warriss, P. D. (2000). Meat Science: An Introductory Text, CAB International, Wallingford, UK.

Wheeler, T. L., Savell, J. W., Cross, H. R., Lunt, D. K. & Smith, S. B. (1990). Mechanisms Associated with the Variation in Tenderness of Meat from Brahman and Hereford Cattle. *Journal of Animal Science,* 68: 4206-4220.

Wood, J. D., Enser, M., Fisher, A. V, Nute, G. R., Richardson, R. I. & Sheard, P. R. (1999). Manipulating Meat Quality and Composition. In: proceedings of the Animal Nutrition and Metabolism Group Symposium on 'Improving Meat Production for Future Needs, the Summer Meeting of the Nutrition Society held at University of Surrey, 58, 363-370.

Wood, J. D., Enser, M., Fisher, A. V., Nute, G. R., Sheard, P. R., Richardson, R. I., Hughes, S. I. & Whittington, F. M. (2008). Fat deposition, fatty acid composition and meat quality. *Meat Science,* 78: 343-358.

Wood, J. D., Richardson, R. I., Nute, G. R., Fisher, A. V., Campo, M. M., Kasapidou, E., Sheard P. R. & Enser, M. (2003). Effects of Fatty Acids on Meat Quality. *Meat Science,* 66: 21-32.

Young, O. A., Reid, D. H. & Scales, G. H. (1993). Effect of breed and ultimate pH on the odour and flavour of sheep meat. *New Zealand Journal of Agricultural Research,* 36: 363-370.