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Meat quality of (*Bos indicus*) cattle finished on different concentrate feeds

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ABSTRACT. The study investigated meat quality of bulls fed concentrate feeds and hay. The treatments were hay *ad libitum* + dried cafeteria leftover 4 kg DM d^{-1} (D1); hay *ad libitum* + wheat bran 4 kg DM d^{-1} (D2); hay *ad libitum* + 4 maize grain 4 kg DM d^{-1} (D3); hay *ad libitum* + mix 4 kg DM d^{-1} (1:1, wheat bran to maize grain, respectively (D4)); hay *ad libitum* + scrambled whole groundnut 4 kg DM d^{-1} (D5); and hay *ad libitum* + mix of each ingredient 4 kg DM d^{-1}(D6)). Samples from *longissimus lumborum* muscle were taken in triplicate. Beef from bulls fed D5 had highest ($p < 0.05$) protein and fat than those fed other treatments. However, bulls finished in D3 had similar fat to those fed with whole ground nut. Highest meat tenderness ($p < 0.05$) recorded at 24th followed by 16th d than those aged on other periods. Beef from D6 produced lean meat, which is acceptable to consumer and market demand than D3, produced carcass with highest fat coverage This study confirmed that meat from D6 had an acceptable quality attribute suggesting the breed could serve as a potential source in red meat industry.

Keywords: cooking loss; purge; shear force.

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Introduction

Ruminants have a crucial role in agriculture in many parts of the world particularly in the tropics and sub-tropics. Meat is one of the most important foods in the world and in some countries it is considered an essential product with very high consumption rates. Meat products are an important component of a healthy and well balanced diet as a result of its nutritional richness. It is one of the most nutritious foods that humans can consume, particularly in terms of supplying high-quality protein (essential amino acids), minerals (especially iron) and essential vitamins. Meat is rich source of protein with high biological value, micronutrients including iron, selenium, zinc and vitamin B1, fatty acids and other bioactive compounds. Meat is composed primarily of water, protein and lipids, with low percentages of carbohydrates, vitamins and minerals. Red meat has several attributes that differentiate it from white meat producers such as pork and chicken in terms of iron and zinc contents, vitamin B12 and fatty acid composition (Williams & Droulez, 2010).

Many factors can dictate ruminant meat quality these includes; level of nutrition, breed, age, sex, climate, animal handling and slaughtering procedures and post-harvest processing (Guerrero, Valero, Campo, & Sanudo, 2013). Among these, nutrition plays an important role in the determination of meat quality Van Elswyk and McNeill (2014) have noted that feeding grass lowers the total fat content of meat as compared to meat from grain feed cattle. Moreover, type of feed has effect on fat content, pH, texture, instrumental color, and nutritional composition (Jacques, Berthiaume, & Cinq-Mars, 2011).

The final composition of beef is known to be impacted by diet, specifically the lipid components which are recognized to have consumer dietary implications (Wood et al., 2003). Previous reports also showed that diet had effect on the content of the long-chain health-enhancing omega 3 fatty acids in ruminant meat products (Scollan et al., 2006). Meat products quality attributes such as protein, fatty acid compositions, vitamins and minerals have been considered as an important parameter of consumer preference (Scollan et al., 2006; Pethick, Ball, Banks, & Hocquette, 2011), in addition, related reports noted that the criteria for determining meat quality are pH, water holding capacity and chemical composition of meat (Gustavson, Cederberg, Sonesson, van Otterdijk, & Meybeck, 2011). Literature also indicates that the most valuable components of meat from the nutritional and post-harvest handling are water, fat, protein and minerals (Adam, Atta, & Ismail, 2010). Moreover, flavor, tenderness and juiciness are the most important quality traits for the overall likability of beef, consumers have been showing demand for beef with better tenderness according to the previous reports, and, tenderness is ranked higher than price when it comes to the purchasing decision of consumers (Reicks et al., 2011).

Information on meat quality is paramount important to meet quality requirements to satisfy consumer demands. In addition, meat industry in the tropics must comply with certain quality standards to meet consumer demands and remain competitive in the global market. In this context, it is necessary to know the factors that can affect meat and carcass quality. In the tropics, there is high choice and demand for red meat produced from mutton, chevon and beef associated with feeding customs and tradition (Teklebrhan, 2012). However, there is paucity of information on complete beef quality parameters. Hence, Evaluation of meat quality parameters correlated with tenderness and meat color such as pH, water-holding capacity, shear force and fatty acids are important because of their relationship with quality and consumer acceptance (Schönfeldt & Strydom, 2011). Hararghe Highlang breed is predominantly found in eastern and western highlands of eastern Ethiopia, which is in close proximity to the study site, the breed is characterized by docile, higher weight gain, and suitable breed for feedlot industry in Ethiopia and the tropics. Therefore, the objective of this study was to elucidate meat quality of Hararghe Highland cattle finished on different concentrate feeds.

Material and methods

Study site

The study was conducted at Haramaya University beef fattening unit. It is located at 9.0˚N and 42.0˚E and 515 km east of Addis Ababa, Ethiopia. The site is situated at an altitude of 1950 m. a.s.l., and has an average temperature of 16˚C and mean annual rainfall of 790 mm (Mishra, Kidan, Kibret, Assen, & Eshetu, 2004).

Animal management

All animal procedures were approved by the Animal Care Committee Haramaya University, Ethiopia. Beef animals with average weight 219.68 ± 0.10 kg (mean ± SD) and an age of 4 ± 0.61 years were kept under tie stall with no grazing in the feedlot barn for the study. Based on their initial body weight bulls were grouped into five blocks (six animals in each block). Animals in each block were received one of the six dietary groups and the chemical composition of the feed ingredients are given in Table 1. The experimental diets were hay *ad libitum* + dried cafeteria leftover 4 kg DM d^{-1} (D1); hay *ad libitum* + wheat bran 4 kg DM d^{-1} (D2); hay *ad libitum* + 4 maize grain 4 kg DM d^{-1} (D3); hay *ad libitum* + mix 4 kg DM d^{-1} (1:1, wheat bran to maize grain, respectively (D4)); hay *ad libitum* + scrambled whole groundnut 4 kg DM d^{-1} (D5) and hay *ad libitum* + mix 4 kg DM d^{-1} (equal proportion of maize grain, wheat bran, dried cafeteria leftover and scrambled whole groundnut (D6)). Hararghe Highland bulls were finished for three months and slaughtered for meat quality studies.

Table 1. Chemical composition of feed ingredients.

Feed items	DM bases (%)						
	DM	Ash	CP	EE	NDF	ADF	ADL
Hay	94.2	9.4	5.5	2.1	75.8	46.2	8.3
Dried cafeteria left-over	92.2	3.0	11.8	7.6	23.5	4.0	2.9
Wheat bran	93.1	3.8	15.2	4.8	43.0	9.5	1.9
Ground maize grain	88.9	2.2	7.1	5.3	27.9	3.9	0.5
Ground whole ground nut	90.6	2.5	49.0	40.0	16.4	7.2	0.98

ADF = Acid Detergent Fiber; ADL = Acid Detergent Lignin; CP = Crude Protein; DM = Dry Matter; EE = Ether Extracts; NDF = Neutral Detergent Fiber.

Sampling procedures

Meat samples from the *longissimus lumborum* (LL) muscle were taken for meat quality study. Five samples per treatment were frozen at -20˚C until use for proximate composition such as moisture, protein, fat and minerals. Meat samples were aged at 4 ˚C for different periods (0, 8, 16 and 24 d), to determine meat pH, Purge Loss (PL), Cooking Loss (CL) and tenderness. Frozen samples were thawed to 4˚C before measurement for meat quality study.

Proximate composition of meat

Proximate compositions of meat quality including moisture, protein, fat and minerals were determined (Association Official Analytical Chemists [AOAC], 2011). For each quality variables five samples per treatment were used for analysis.

pH measurement

The pH value of meat samples was performed in triplicate for all aging periods according to the procedure of AOAC (2011). The pH of meat samples was measured using a pH meter (AOAC, 2011), which was calibrated before each sampling time using standard buffers at pH 4.0 and 7.0 and was used for immediate measurement of pH using a portable pH meter (Starter 300; Ohaus Instruments Co. Ltd., Shanghai, China)

Drip loss (DL)

For each sample 100 g fresh meat was vacuum packed using a plastic bag and aged at 0, 8, 16 and 24 days. Then each packed meat was removed from their bags after the relevant ageing periods, and re-weighed. Then, percentage of weight loss was expressed as a percentage of the original sample weight (Strydom & Hope-Jones, 2014).

Cooking loss

Meat samples were thawed at 4°C overnight and then cooked using stove for about 20-25 min until the internal temperature reached 71°C (American Meat Science Association [AMSA], 1995), After cooking, the samples were then cooled at room temperature for 2h and weighed again. The cooking loss was determined by the difference in the weight of the meat before and after cooking in percentage.

Meat tenderness

Cooked meat samples that had been used for cooking loss determination were used to determine shear force. samples for tenderness was determined using (razor blade shear (RB; 8.9 mm width) (Cavitt, Youm, Meullenet, Owens & Xiong, 2004). Briefly, three subsamples were removed with a cross section of 1 × 1 cm and cut parallel to the muscle fibres from each cooked samples. The average of three subsamples was used as the sheer force value for a sample.

Statistical analysis

Data on meat qualities were subjected to analysis of variance (ANOVA) using the General Linear Model (GLM) procedure of SAS (Statistical Analysis System [SAS], 2003). The differences among treatment means was tested using Tukeys' studentized range (HSD) test. The model used for data analysis was:

$$Y_{ij} = \mu + T_i + B_j + \varepsilon_{ijk}$$

where:
Y_{ij} = response variable
μ = overall mean
Ti = treatment effect (diet or aging period)
B_j = block effect
$\mathcal{E}_{ijk}$ = random error term

Results

Proximate composition of meat

The chemical composition of beef meat was affected ($p < 0.05$) by diet groups except moisture and mineral content ($p > 0.05$) (Table 2). The protein, fat and moisture of Hararghe Highland beef meat ranged between 22.2-25.0, 4.4-9 and 72.7- 74.0 %, respectively. The meat from bulls fed D5 had highest ($p < 0.05$) protein and fat than those bulls fed with other dietary groups. However, meat of bulls finished on D3 had similar fat to bulls fed D5. The production of meat of higher protein and fat is due to highest fat and protein content of the feed (Table 2).

Total ash and minerals (Calcium, iron, zinc and selenium) variations were not ($p > 0.05$) detected among dietary groups. The ash content of Hararghe Highland beef ranges between 0.98-1.05 percent. Meat from bulls fed on D3 tended to be lowered total ash as compared with other dietary groups. The minerals such as calcium, iron and zinc contents of the beef were 4.0-4.5, 1.6-2.0 and 4.4-4.8 mg per 100 g of meat, respectively. While the selenium content of Hararghe Highland was 16.5-17.2 μg per 100 g of meat (Table 2).

Table 2. Proximate composition of meat.

Attributes	Diet effect (on dry matter basis)						SEM	P
	D1	D2	D3	D4	D5	D6		
	Proximate composition (%)							
Moisture	72.7	73.5	73.7	73.0	73.9.	74.0	0.12	0.98
Protein	22.0[bc]	23.6[b]	22.1[bc]	23.5[b]	25.0[a]	23.2[b]	0.24	.001
Fat	5.6[b]	5.7[b]	7.4[ab]	5.8[b]	9.0[a]	5.6[b]	1.06	.001
Total ash	1.01	1.03	0.98	1.04	1.05	1.02	0.05	1.00
	Major and trace minerals (mg/100g)							
Ca	4.0	4.6	4.4	4.1	4.3	4.5	0.01	0.90
Fe	1.7	1.6	1.7	1.8	2.0	1.9	0.07	0.88
Zn	4.5	4.7	4.5	4.4	4.8	4.4	0.02	0.33
Se (μg 100 g^{-1})	16.5	17.2	17.2	16.7	17.0	16.9	0.01	0.91

[a,b,c]mean values indicate significant difference among different concentrate treatments; SEM = standard error of the mean; Diet 1 (D1) = Hay *ad libitum* +dried cafeteria leftover 4kg DM d^{-1}; Diet 2 (D2) = hay *ad libitum* + wheat bran 4kg DM d^{-1}; Diet 3 (D3) = hay *ad libitum* + maize grain 4 kg DM d^{-1}; Diet (D4) = hay *ad libitum* + mix 4kg DM d^{-1} (1:1, wheat bran to maize grain, respectively); Diet 5 (D5) = Hay *ad libitum* + scrambled whole groundnut 4kg DM d^{-1}; Diet 6 (D6) = hay *ad libitum* + mix 4kg DM d^{-1} (equal proportion of maize grain, wheat bran, dried cafeteria leftover and scrambled whole groundnut).

Nutrition on physical quality of meat

The physical qualities of beef were influenced by the nutritional regimes (Table 3). Bulls fed D1 had highest, while D3 had lowest ($p > 0.01$) drip loss compared with other dietary groups. Cooking loss was highest ($p > 0.01$) when bulls fed D3 followed by D1 than those other dietary groups. Bulls received D3 had the most tender meat compared with other groups, while bulls fed D1 produced less tender meat than bulls fed D4, D5 and D6.

Table 3. Effect of diet on physical quality of meat.

Attributes	Diet effect (on dry matter basis)						SEM	P
	D1	D2	D3	D4	D5	D6		
pH	5.01	5.15	5.23	5.71	5.03	5.21	0.42	0.18
DL (%)	10.1[a]	4.5[b]	1.1[c]	4.9[b]	5.7[b]	5.9[b]	0.34	.001
CL (%)	38[a]	31.4[b]	42.9[a]	33.6[b]	32.9[b]	33.6[b]	0.41	.001
Shear force (N)	71.0[d]	61.4[c]	35.4[a]	57.0[b]	48.0[b]	49.0[b]	2.51	.002

Aging on physical quality of meat

The pH, drip loss and cooking loss variables remained the same ($p > 0.05$) across aging periods. The pH, drip and cooking loss of the meat were 5.51-5.61, 2.9-3.9 and 33-36.6 %, respectively. Meat of Hararghe Highland revealed a decreasing trend of pH across the aging periods as move from low to high aging periods (Table 4). While drip and cooking loss percentage of beef tended to be increased from low to high aging periods.

Beef tenderness or shear force was affected ($p < 0.05$) by aging periods. Accordingly, better beef tenderness ($p < 0.05$) was recorded at 24 and 16^{th} d aging than beef of other aging periods. Though there was numerical difference, similar ($p > 0.05$) tenderness values were noted between eight days aging and meat without aging (Table 4).

Table 4. The effect of aging time on physical quality of beef meat.

Attributes	Aging (days)				SEM	P
	0	8	16	24		
pH	5.61	5.55	5.53	5.51	0.01	1.00
DL (%)	2.9	3.5	3.7	3.9	0.15	0.14
CL (%)	33	34.4	35.9	36.6	0.05	0.06
Shear force (N)	66.0[b]	57.0[b]	51.4[a]	49.0[a]	0.09	0.04

[a,b]mean values indicate significant difference among different aging ; CL = cooking loss; P= probability DL= purge loss; SEM = Standard error of the mean.

Discussion

Beef from bulls fed D5 increased protein and fat while lowered total ash content as compared with other dietary groups. Elevated protein and fat in the diet can be caused by highest fat and protein content of the diet. The protein content of *longissimus lumbarum* (loin) muscle of Hararghe Highland ranges between 22 to 25%. The protein content of the beef was comparable to the previous reports (Williams, 2007; Nikmaram, Said, & Emamjomeh, 2011). However, it was higher than the value reported by Kasap, Kaić, Širić, Antunović, and Mioč (2017). Likewise, the fat of beef from Hararghe Highland was consistent with the previous results

(Williams, 2007). The fat % obtained in this study was lower than Chávez et al. (2012), who found higher fat from Bos *indicus* and *taurus* cattle. However, the fat from these cattle is higher than the recent findings of Kasap et al. (2017). This study suggested that, the carcass from Hararghe Highland breed has moderate fat coverage and is important in reducing chilling losses of the carcass and improvement of juiciness and flavour of meat (Teklebrhan, Yoseph, & Mengistu, 2013). The moisture content of beef found in this study supports the findings reported from beef cattle (Williams, 2007; Adam et al., 2010; Nikmaram et al., 2011; Chávez et al., 2012). However, moisture content of Hararghe Highland was lowered as compared to Bos *taurus* cattle (Chávez et al., 2012) and sheep (Kasap et al., 2017). The total ash content of Hararghe Highland meat was comparable to the previous reports (Williams, 2007; Nikmaram et al., 2011). Moreover, it was related to the total ash contents of small ruminant meat (Chávez et al., 2012; Kasap et al., 2017). Beef is primarily the richest sources of the minerals such as iron, zinc, calcium and selenium. The iron in meat is mostly haem-iron which is well absorbed, and meat protein also appears to enhance the absorption of iron from meat. Similarly, absorption of zinc from a diet rich in animal protein is greater than protein from plant foods, and the requirements of zinc may be as much as 50% higher for vegetarians. The present study showed that beef from Hararghe Highland had higher iron, zinc and, selenium than veal and mutton (Williams, 2007). However, the indexes of Ca, Fe and Zn in the present study were lowered than the previous report (Kasap et al., 2017).

Nutrition and meat aging influenced the physical quality of beef, water holding capacity (cooking loss and drip loss) measure decrease in edible meat mass for human consumption and saleable yields (Gustavson et al., 2011). The increased fat in bulls fed D3 reduced weight loss by dripping, while increased weight loss by cooking compared to other dietary groups. However, aging periods did not influence cooking loss ($p > 0.05$), though an increasing trend was noticed as progressing with higher aging periods. Similarly, other studies reported no aging effect on cooking loss when evaluated in beef (Hergenreder et al., 2013; Grayson, King, Shackelford, Koohmaraie, & Wheeler, 2014; Aroeira et al., 2016; Choe, Stuart, & Kim, 2016; Francisco et al., 2017; Kim et al., 2018). In the present study as meat aging progressed, meat gradually lost its water retention potential, this might be associated with increased protein degradation during meat aging (Strydom, Lühl, Kahl, & Hoffman, 2016; Aroeira et al., 2016).

The pH of Hararghe Highland beef was slightly lower than those of temperate breeds, this might be due to B. *indicus* animals have higher glycolytic rates in the early post mortem condition than Bos *taurus* animals (Aroeira et al. 2016). However, the value obtained for this cattle breed was within the normal pH range of meat (5.4 to 5.7; Renerre, 1990). In this study, the pH remained unchanged by the diet and aging periods, with a slight decrease in pH as progressed to higher aging periods. The study by Strydom et al. (2016) and Aroeira et al. (2016), also noted a decreasing trend towards higher aging days. The pH decrease after aging can occur due to an ionic imbalance caused by the denaturation of buffering proteins by freezing (Leygonie, Britz, & Hoffman, 2012) and by an increase in solute concentration due to greater exudate loss (Aroeira et al., 2016).

Tenderness improvement can be achieved by plane of nutrition and post-mortem aging. For example, in the present study, the improved tenderness in bulls fed D3 is caused by higher fat in D3 comparing with other dietary groups. Improvement of tenderness through aging is due to the loss of structural integrity caused by the intracellular ice crystals that disrupt the physical structures, including a large portion of myofibrils (Grayson et al., 2014). Beef from Hararghe Highland (*Bos indicus*) had lower tenderness as compared with Bos *taurus* temperate breeds. This might due to increase calpastatin activity during post-mortem in *B. indicus* breeds according to previous studies (Johnson, Calkins, Huffman, Johnson, & Hargrove, 1990). The beef from Hararghe Highland aged at 16 d can be classified as tender meat according to tenderness classification system (Destefanis, Brugiapaglia, Barge, & Dal Molin, 2008). Similarly, other studies also reported improvement of tenderness in aged beef (Grayson et al., 2014; Francisco et al., 2017). In contrary other reports found similar shear force value at different aging periods (Choe et al., 2016; Kim et al., 2018).

Conclusion

Meat produced from beef fed D3 increased protein and fat content than those beef from other treatments. Beef from D6 diet produced lean meat, which is acceptable to the current consumer demand and market of meat as compared with D3, produced carcass with highest fat coverage. Beef from Hararghe Highland (*Bos indicus)* produced sufficient amount essential minerals such as iron, zinc and selenium. Bulls fed D3 improved tenderness as compared with other dietary groups. Tenderness can be achieved by aging beef earlier at 16 and better value is attained later at 24 day. This study suggested that Hararghe Highland beef is a tropical breed can produce intermediate tender meat without aging. This study confirmed that meat from Hararghe Highland cattle fed D6 has an acceptable quality attributes and, thus implies the breed could serve as a potential source in the red meat industry.

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