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Carcass and meat quality characteristics of Arsi-Bale goats supplemented with different levels of air-dried *Moringa stenopetala* leaf

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Abstract

This study was conducted to assess the effect of air-dried *Moringa stenopetala* leaf (MSL) supplementation on carcass components and meat quality in Arsi-Bale goats. A total of 24 yearling goats with initial body weight of 13.6±0.25 kg were randomly divided into four treatments with six goats each. All goats received a basal diet of natural grass hay *ad libitum* and 340 g head^{-1} d^{-1} concentrate. The treatment diets contain a control diet without supplementation (T1) and diets supplemented with MSL at a rate of 120 g head^{-1} d^{-1} (T2), 170 g head^{-1} d^{-1} (T3) and 220 g head^{-1} d^{-1} (T4). The results indicated that the average slaughter weight of goats reared on T3 and T4 was 18.2 and 18.3 kg, respectively, being ($P < 0.05$) higher than those of T1 (15.8 kg) and T2 (16.5 kg). Goats fed on T3 and T4 diets had higher ($P < 0.05$) daily weight gain compared with those of T1 and T2. The hot carcass weight in goats reared on T3 and T4 diets was 6.40 and 7.30 kg, respectively, being ($P < 0.05$) higher than those of T1 (4.81 kg) and T2 (5.06 kg). Goats reared on T4 had higher ($P < 0.05$) dressing percentage than those reared in other treatment diets. The rib-eye area in goats reared on T2, T3 and T4 diets was higher ($P < 0.05$) than those of T1. The protein content of the meat in goats reared on T3 and T4 was 24.0 and 26.4 %, respectively being significantly higher than those of T1 (19.1 %) and T2 (20.1 %). In conclusion, the supplementation of MSL to natural grass hay improved the weight gain and carcass parts of Arsi-Bale goats indicating Moringa leaves as alternative protein supplements to poor quality forages.

Keywords: Arsi-Bale goats, carcass traits, meat quality, natural grass hay, *Moringa stenopetala* leaf, supplementation

1 Introduction

There are approximately 570 breeds and types of goats in the world of which 89 are found in Africa (Gala, 2005). The present estimated population of goats in Ethiopia is 29.3 million (CSA, 2014). The goats play an important role by improving the livelihood of resource challenged farmers by creating alternative employment opportunities, enhancing family income by sale of live animals, skin, manure, etc. Therefore, demand for goat's meat is on the rise throughout the world especially in Ethiopia. This is mainly due to increased human population coupled with income growth. However, regardless of their attributes, the productivity of goats remains low mainly due to diseases, genotype, management and nutrition (Simela & Merkel, 2008).

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One of the most important nutritional constraints in goat production in the tropics is underfeeding mainly attributed to limitations of feed in both quantity and quality. The situation is aggravated during the dry season where natural pastures became over-matured being critically deficient in protein and energy contents. As a result, large flocks of productive livestock cannot be maintained on such feeds that hardly meet even the basic maintenance requirement of farm animals. It is thus imperative to supplement the available poor quality feed resources with some amount of concentrates for enhanced productivity of farm animals. However, the use of conventional feeds as a supplement is usually limited under smallholder livestock production systems due to inaccessibility and high cost of such feed ingredients.

In order to mitigate the problems associated with the lack of protein supplement, there is a need to look for alternative cheap protein sources from unconventional feed resources that are easily accessible by the smallholder farmers (Manaye *et al.*, 2009). Leaves of *Moringa* spp. could be one possible source of protein both for humans and livestock. Among the Moringa species, *Moringa stenopetala* is endemic to southern Ethiopia, which is unique as it does not shed its leaves even during the dry season (Thurber & Fahey, 2009). Recent studies conducted by Negesse *et al.* (2009), Melesse *et al.* (2009, 2012) and Debela & Tolera (2013) have indicated that the leaves of *M. stenopetala* are rich in protein (28.2–36.1 %) and contain substantial amounts of essential amino acids as well as macro and trace minerals.

There are several studies indicating the use of the fresh foliage of *Moringa* spp. as a source of livestock feed. Studies by Sánchez *et al.* (2006) reported significant increase in milk yield of Creole dairy cows supplemented with *Moringa oleifera* leaves. Goats supplemented with *M. oleifera* leaves at 20 and 50 % levels of total daily forage allowance had higher live-weight gains, and higher digestibility of nutrients (Aregheore, 2002). Improvements in nutrient intake, growth performances and nutrient retention have been also obtained from sheep supplemented with air-dried *M. stenopetala* leaf to the basal diet of Rhodes grass hay (Gebregiorgis *et al.*, 2011). Moreover, Melesse *et al.* (2011, 2013) reported enhanced improvements in the feed intake, growth performances and carcass characteristics of growing dual-purpose chickens fed with graded levels of *M. stenopetala* leaf meal by replacing roasted soybean seed. However, information on the feeding values of *M. stenopetala* leaf on the carcass components and meat quality of male goats in Ethiopia is not available. Thus, this research was carried out to assess the effect of feeding graded levels of air-dried *M. stenopetala* leaf supplemented to a basal diet of natural grass hay on the carcass characteristics and meat quality of Arsi-Bale goats.

2 Materials and methods

2.1 *Experimental site*

The experiment was carried out at the Animal Farm of the School of Animal and Range Sciences, Hawassa University (Ethiopia), which lies geographically between 7°55′N latitude and 38°N29′E longitude at an altitude of 1700 m asl. The average annual rainfall ranges from 800 mm to 1100 mm. The mean minimum and maximum temperatures in the study area are 13.5°C and 27.6°C, respectively (NMA, 2012).

2.2 *Preparation of experimental rations*

Fresh *M. stenopetala* leaves were collected from farmers of Mirab Abaya near to Arbaminch city which is located between 6°4′N latitude and 37°34′E longitude at an altitude of 1220 m asl. The fresh leaves were harvested from available trees regardless of tree age. The collected leaves were then trimmed from twigs on a plastic sheet and dried under the shade to prevent the loss of vitamins and volatile nutrients. During the drying process, regular turning of leaves was done to ensure uniform drying for safe storage. The air-dried Moringa leaves were finally transported to the experimental site and ground into coarse powder which hereafter is referred to as air-dried *M. stenopetala* leaf (MSL). The ground leaf was packed in bags of 100 kg and stored until used. Natural grass hay was bought from a nearby private farm and hand chopped into the size of 3 to 5 cm for ease of feeding. Samples of MSL and various ingredients of the experimental ration were subjected to chemical composition analysis before being used in the formulation of experimental diets.

2.3 *Experimental animals and their management*

In this experiment, about 1 year old (age determined by dentition) 24 Arsi-Bale male goats were purchased from local market and transported to the experimental site. They were then quarantined for a fortnight, during which they were treated with 250 mg of albendazole (Chengdu Qiankun veterinary pharmaceuticals Co. ltd. China), administered through drenching gun for deworming the animals. Moreover, 1.5 ml Oxytetracycline (*ibid*) was provided intravenous for three days to treat the animals from possible respiratory diseases and physical injuries incurred during the transportation. The barns were also sprayed with Diazinone (*ibid*) to take care of any ecto-parasite infestation.

At the end of the quarantine period, the goats were ear tagged and weighed (prior to being offered any feed) for two consecutive days and the body weight was averaged. Then they were housed in individual pens and each animal was provided with individual feeder and watering trough.

2.4 Experimental design and treatment diets

The feeding trial was a completely randomized design (CRD) consisting of one control and three supplemental treatment diets with six goats randomly assigned to each treatment. The trial was conducted for 75 days exclusive a 15 days adaptation period. All the experimental goats had *ad libitum* access to natural grass hay and water. They were also provided with a concentrate at a rate of 2.5 % of their body weight according to the recommendation of McDonald *et al.* (2010). Consequently, as the average initial body weight of the goats was 13.6 kg, the calculated concentrate supplied per goat and day was 340 g. The diets therefore contained 340 g concentrate only (T1), 340 g concentrate plus 35 % MSL supplementation (120 g) (T2), 340 g concentrate plus 50 % MSL supplementation (170 g) (T3) and 340 g concentrate plus 65 % MSL supplementation (220 g) (T4). Accordingly, the total concentrate/MSL mixture offered to T1, T2, T3 and T4 treatment groups were 340, 460, 510 and 560 g head^{-1} d^{-1}, respectively. The concentrate offered was a mixture of 50 % wheat bran, 35 % maize, 14 % Noug seed (*Guizotia abyssinica*) cake and 1 % salt. Natural grass hay and the concentrate/MSL mixture were offered separately.

2.5 Data collection procedures

2.5.1 Feed consumption

Samples of daily feed offered and refused were collected, measured and pooled over the experimental period for each animal and used for chemical analysis. The daily average feed intake was determined by the difference between the amounts of feed offered and refused. Body weight of each goat was recorded every fortnight after overnight fasting.

2.5.2 Parts of the carcass

For the evaluation of carcass components, all goats were fasted overnight, weighed (here after referred as slaughter weight) and slaughtered. The weights of the following carcass parts were then recorded: head, skin, neck, thorax, lumbar, rack, heart, lung, trachea, liver, gall bladder, spleen, testis, kidneys, trotters, rumen, small and large intestines. Hot carcass weight was determined after the removal of the head, hide, intestinal tract, and internal organs. Dressing percentage was then calculated as proportion of hot carcass weight to slaughter weight. The rib-eye muscle (*Longissimus dorsi*) area of each animal was determined according to standard procedure using a digital planimeter (portable area meter, model LI 3000A) as suggested by AOAC (1995). The cross-sectional area of rib-eye muscle between the 12th and 13th ribs were traced on transparency paper from the right and left side and measured by using a planimeter. The average of the right and left cross-sectional areas was then taken as a rib-eye muscle area.

2.5.3 Meat quality

Cooking loss

The cooking loss was determined by using 1.5 g of the meat sample from *L. dorsi* muscle in replication. The meat was placed in a test tube (for indirect boiling) and immersed in a water bath having a temperature of 85°C and cooked for 30 minutes after which the meat was cooled to room temperature and then weighed. The difference was then recorded as the cooking loss (AOAC, 1995).

Meat pH

The meat pH was measured at 50 minutes of post mortem in the *L. dorsi* muscle at the first lumbar using a digital pH meter (IS/ISO 3100), which was equipped with a penetrating electrode. The pH meter was calibrated with pH values of 4, 7 and 9 standard solutions before each measurement was undertaken.

Intramuscular fat

The determination of the intramuscular fat (ether extract) was carried out according to the procedures of AOAC (1995). The intramuscular fat in *L. dorsi* muscle was assessed by taking one gram of dried meat sample which was folded in a filter paper and placed in Soxhlet apparatus. It was then refluxed 30–40 times using petroleum benzene (boiling point 60–80°C) until all the fat from the sample was transferred to the petroleum ether. The defatted sample was then transferred to desiccators and allowed to cool overnight and reweighed using sensitive balance.

2.6 Chemical analysis of the feed

The analysis of dry matter (DM), ash and ether extract (EE) was performed according to AOAC (1995). Accordingly, the DM content of the feed was determined by drying the samples at 105°C overnight. Ash was determined by combusting the samples at 550°C for 5 h. Nitrogen (N) was extracted with Kjeldahl method and then the crude protein (CP) was calculated as $N \times 6.25$ (AOAC, 1995). The contents of acid detergent fibre (ADF) and neutral detergent fibre (NDF) were analysed using the method of Van Soest *et al.* (1991) in an ANKOM® 200 Fibre Analyser (ANKOM Technology Corp., Fairport, NY, USA). All samples were analysed in duplicates at the Animal Nutrition Laboratory of Animal and Range Sciences, Hawassa University.

2.7 Statistical analysis

The data were subjected to Analysis of Variance (ANOVA) using the GLM of SAS (SAS, 2010, ver. 9.3). When significant differences were observed among treatment means, they were separated by Duncan multiple range test. Comparisons with $P < 0.05$ were considered significant and all statements of statistical differences were based on this level unless noted otherwise.

The following linear model summarizes the statistics employed to analyse the data:

$$Y_{ij} = \mu + A_i + e_{ij} \text{ ; where:}$$

Y_{ij} = the observed j^{th} variable in the i^{th} treatment diet (fixed factor)

μ = overall mean of the observed variable

A_i = effect due to i^{th} treatment diets (i = 0, 120, 170, 220 g head^{-1} d^{-1})

e_{ij} = random residual error

3 Results

3.1 Chemical composition of experimental feed

Chemical composition of the ingredients of the experimental ration is presented in Table 1. The DM content was more or less similar across the feed ingredients although it was slightly higher in grass hay. The ash content was lowest for the maize grain while it was highest in MSL. The CP content was highest for the MSL followed by that of the Noug seed cake. The results also indicated that the EE content was highest for Noug seed cake and lowest for grass hay. The NDF and ADF contents were highest for grass hay while they were lowest in MSL.

3.2 Nutrient contents of experimental diets

The results from Table 2 indicate that the DM content of the experimental diets was more or less similar while the highest ash and EE contents were observed with 170 and 220 g head^{-1} d^{-1} MSL supplemented diets. The CP content was highest in diets supplemented with 220 g MSL and was lowest in the control diet. The ADF and NDF contents were generally high for the control diet and decreased with increasing levels of MSL supplementation in the treatment diets.

3.3 Body weight

As presented in Table 3, the goats supplemented with 170 and 220 g MSL had significantly higher final body weight ($P < 0.01$) and weight gain ($P < 0.001$) than those of the control and 120 g supplemented group. There was no significant difference between goats supplemented with 170 and 220 g MSL as well as between those reared on the control and 120 g MSL supplemented diets.

Table 1: *Nutrient compositions (g kg^{-1} DM) of the ingredients of the concentrate, natural grass hay and air-dried Moringa stenopetala leaf*

Nutrients	*Ingredients of the concentrate mix*			*Natural grass hay*	*Moringa stenopetala*
	Maize grain	*Wheat bran*	*Noug seed cake**		
Dry matter	933	936	939	956	944
Crude protein	65.0	160	249	51.0	295
Ether extract	96.0	54.2	105	28.6	59.0
NDF	412	365	325	612	178
ADF	49.0	175	215	257	165

* Guizotia abyssinica; DM = dry matter; NDF = neutral detergent fibre; ADF = acid detergent fibre

Table 2: *The average nutrient compositions (g kg^{-1} DM) of the experimental diets supplemented with various levels air-dried Moringa stenopetala leaf*

Nutrients	*Levels of Moringa leaf supplementation* (g head^{-1} d^{-1})			
	0	*120*	*170*	*220*
Dry matter	923	927	936	946
Ash	62.0	71.0	80.1	120
Crude protein	160	167	172	187
Ether extract	57.0	61.0	87.0	95.0
Neutral detergent fibre	693	455	365	336
Acid detergent fibre	561	383	238	225

Table 3: *The effect of various levels of air-dried Moringa stenopetala leaf supplementation on the growth performances of Arsi-Bale goats*

Growth performances	*Levels of Moringa leaf supplementation (g head^{-1} d^{-1})*				*SE*	*LS*
	0	*120*	*170*	*220*		
Initial body weight (kg)	13.5	13.8	13.6	13.7	0.25	NS
Final body weight (kg)	15.8 ^{b}	16.5 ^{b}	18.2 ^{a}	18.5 ^{a}	1.07	**
Total weight gain (kg)	2.26 ^{b}	2.73 ^{b}	4.65 ^{a}	4.80 ^{a}	1.05	***
Average daily gain (g)	54.0 ^{b}	58.1 ^{b}	111 ^{a}	114 ^{a}	10.4	***

Means with different lowercase letters in the same row are significantly different ($p < 0.05$)
SE = standard error of the mean; * = $p < 0.05$; ** = $p < 0.01$; *** = $p < 0.001$; NS = not significant; LS = level of significance

3.4 Carcass yield and dressing percentage

The average slaughter weight of goats supplemented with 170 and 220 g MSL was 18.2 and 18.5 kg, respectively, being significantly higher than those of the control and with 120 g MSL supplemented goats (Table 4). Similarly, the hot carcass weight varied ($P < 0.01$) across the treatment diets with higher values being observed in goats supplemented with 220 g MSL followed by those of 170 g and 120 g. The results further indicated that the average dressing percentage was higher ($P < 0.05$) in goats supplemented with 220 g MSL than those reared on the control diet.

The results indicated differences ($P < 0.01$) in rib-eye area between goats supplemented with various levels of MSL. The weight of the neck also varied across treatment diets with higher values being observed in goats supplemented with 170 and 220 g MSL. The weight of the lumbar region in all supplemented goats was higher ($P < 0.05$) than those reared on the control diet. The weight of the heart was higher ($P < 0.05$) in goats supplemented with 220 g of MSL than those reared on the control and 120 g supplemented diets. The same was true for the weight of the kidneys.

3.5 Conditionally edible parts of the carcass

As presented in Table 5, the proportional value of lungs varied ($P < 0.05$) across the goats reared on the different diets being higher ($P < 0.05$) in those supplemented with 220 g MSL than those fed on the control diet. The spleen yield was higher ($P < 0.05$) among the goats supplemented with 170 and 220 g MSL. The proportional yields of the head and trotters were higher ($P < 0.05$) in goats supplemented with 220 g MSL than those reared on the control diet. The yield of the large intestine was higher ($P < 0.05$) in goats supplemented with 220 g MSL than those reared on other treatment diets.

Table 4: *The effect of different levels of air-dried Moringa stenopetala leaf supplementation on edible carcass parts of Arsi-Bale goats*

Carcass components (kg)	*Levels of Moringa leaf supplementation (g head^{-1} d^{-1})*				*SE*	*LS*
	0	*120*	*170*	*220*		
Slaughter weight	15.8 ^{b}	16.5 ^{b}	18.2 ^{a}	18.5 ^{a}	1.30	*
Hot carcass weight	4.83 ^{c}	5.26 ^{c}	6.40 ^{b}	7.30 ^{a}	0.37	**
Dressing (%)	30.8 ^{b}	32.5 ^{b}	35.1 ^{ab}	39.7 ^{a}	4.50	*
Rib-eye area (cm2)	4.65 ^{c}	5.96 ^{b}	6.63 ^{a}	7.27 ^{a}	0.51	**
Neck	0.41 ^{b}	0.44 ^{b}	0.49 ^{ab}	0.58 ^{a}	0.10	*
Thorax	1.34 ^{c}	1.35 ^{c}	1.37 ^{b}	1.43 ^{a}	0.01	**
Rack	0.108 ^{b}	0.188 ^{b}	0.213 ^{b}	0.302 ^{a}	0.07	*
Lumbar	0.440 ^{b}	0.574 ^{a}	0.615 ^{a}	0.675 ^{a}	0.10	*
Liver	0.308	0.314	0.363	0.365	0.15	NS
Heart	0.073 ^{b}	0.078 ^{b}	0.130 ^{ab}	0.180 ^{a}	0.06	*
Kidneys	0.026 ^{b}	0.045 ^{ab}	0.053 ^{ab}	0.066 ^{a}	0.025	*

Means with different lowercase letters in the same row are significantly different ($p < 0.05$)
SE = standard error of the mean; * = $p < 0.05$; ** = $p < 0.01$; NS = not significant; LS = level of significance

Table 5: *The effect of diets supplemented with various levels of air-dried Moringa stenopetala leaf on the yield of conditionally edible parts of the carcass in Arsi-Bale goats*

Organs relative to slaughter weight (%)	*Levels of Moringa leaf supplementation (g head^{-1} d^{-1})*				*SE*	*LS*
	0	*120*	*170*	*220*		
Lung	0.81 ^{b}	0.93 ^{b}	1.21 ^{b}	2.04 ^{a}	0.27	*
Testis	0.58	0.64	0.61	1.00	0.19	NS
Head	4.20 ^{b}	5.44 ^{ab}	5.77 ^{ab}	6.75 ^{a}	0.52	*
Trachea	0.74	0.73	0.81	0.81	0.02	NS
Trotters	3.42 ^{b}	4.55 ^{a}	4.40 ^{a}	4.41 ^{a}	0.26	*
Spleen	0.06 ^{b}	0.11 ^{b}	0.25 ^{a}	0.26 ^{a}	0.05	*
Rumen	3.70	3.63	3.60	3.90	0.07	NS
Large intestine	1.34 ^{b}	1.81 ^{b}	1.73 ^{b}	2.71 ^{a}	0.3	*
Small intestine	1.63	1.96	1.76	2.0	0.09	NS
Blood	3.35	3.38	3.11	3.21	0.06	NS
Gallbladder	0.13	0.16	0.20	0.50	0.08	NS
Skin	10.45	10.40	9.10	9.45	0.33	NS

Means with different lowercase letters in the same row are significantly different ($p < 0.05$)
SE = standard error of the mean; * = $p < 0.05$; NS = not significant; LS = level of significance

3.6 Chemical composition of the meat

As shown in Table 6, the contents of protein and fat were higher in the meat from goats fed on diets supplemented with the 170 and 220 g MSL than those reared on the 120 g supplemented and the control diets. The results further indicated that there were no differences among treatments for the other parameters studied.

Table 6: *Chemical composition, pH value and cooking loss of meat in Arsi-Bale goats supplemented with different levels of air-dried Moringa stenopetala leaf*

Parameter	*Levels of Moringa leaf supplementation (g head^{-1} d^{-1})*				*SE*	*LS*
	0	*120*	*170*	*220*		
Ash (%)	1.15	1.06	1.76	1.35	0.76	NS
Moisture (%)	69.0	70.4	71.8	72.9	4.06	NS
Protein (%)	19.1 ^{b}	20.1 ^{b}	24.0 ^{a}	26.5 ^{a}	2.12	*
Fat (%)	4.66 ^{b}	5.10 ^{b}	6.41 ^{a}	7. 60 ^{a}	1.03	*
pH of meat	5.56	5.48	5.45	5.42	0.01	NS
Cooking loss	39.1	39.1	38.9	36.7	2.96	NS

Means with different lowercase letters in the same row are significantly different ($p < 0.05$)
* = $p < 0.05$; NS = not significant; SE = standard error of the mean; LS = level of significance

4 Discussion

4.1 Nutrient composition of Moringa stenopetala and experimental feed

The ash contents of MSL in this study are in accordance with the observations of Dechasa *et al.* (2006) and Melesse *et al.* (2011) for *M. stenopetala* leaves and those of Olugbemi *et al.* (2010a) and Melesse *et al.* (2012) for *M. oleifera* leaves. The CP contents of MSL in the current study are similar to those reported by Melesse *et al.* (2009, 2011, 2012, 2013) for the same plant species. However, higher CP contents were reported by Negesse *et al.* (2009) for *M. stenopetala* leaves which might be attributed to the stage of maturity of leaves as young leaves tend to contain higher protein contents than older ones. The EE contents are within the range of those reported by Melesse *et al.* (2009) for *M. stenopetala* leaves. The NDF and ADF contents in the present study are also comparable to those of Melesse *et al.* (2011) for leaves of the same Moringa species but higher than those of *M. oleifera* reported by Olugbemi *et al.* (2010b). The CP, DM and OM contents of the natural grass hay in the present study are consistent with those reported by Banerjee *et al.* (2013). However, the NDF and ADF contents of the natural grass are lower than those reported by Banerjee *et al.* (2013). This difference might be attributed to the stage of maturity of the grass when it was cut and the way and duration it was stored. The relatively high NDF and ADF contents of the natural grass hay shows that it has a poor nutritional potential and is not adequate to support the maintenance requirements of goats as it contains CP below the minimum level (7 %) required for microbial function (Van Soest, 1994). Consequently, such poor quality roughages must be supplemented with protein sources like leaves of *M. stenopetala* that are easily accessible and affordable for small farmer households.

4.2 Body weight and carcass characteristics

Supplementation of natural grass hay with various levels of MSL has in general resulted in enhanced final body weight and total weight gain. The findings are in good agreement with those of Gebregiorgis *et al.* (2011) who reported that there was a significant improvement in body weights of sheep reared on a basal diet of Rhodes grass hay that was supplemented with different levels of air-dried *M. stenopetala* leaves. Similar to the present findings, Aregheore (2002) also reported that goats supplemented with fresh leaves of *M. oleifera* at 20 and 50 % levels had higher live-weight gains, and higher digestibility of DM, organic matter, energy, CP and NDF than those reared on the basal diet of batiki grass alone.

Dressing percentage, which is an important trait for carcass evaluation is influenced by age, breed, sex, plane of nutrition, management system etc. In the present study, both the slaughter weight and dressing percentage values were considerably higher in goats supplemented with 170 g and 220 g MSL. The observations are in accordance with the reports of Qwele *et al.* (2013) who had observed higher slaughter weight and digestible protein values in goats reared on diets supplemented with *M. oleifera* leaves. This might be explained by the availability of more valuable nutrients, particularly crude protein, due to the supplementation of MSL to the low quality natural grass hay.

The average dressing percentage (irrespective of the treatments) in the present study indicates that it is lower than the value reported by Kebede *et al.* (2008) for adult Arsi-Bale goats. The observed differences might be due to the fact that goats in the present study were young and were still growing. Moreover, the observed differences might be associated with the management differences used by the different scholars as goats in the tropics are not always accustomed to stall feeding conditions unless they are allowed to accustom to the new management environment before the start of the actual trial.

The rib-eye area values in goats supplemented with 120, 170 and 220 g MSL are in accordance with the reports of Kebede *et al.* (2008) and Sebsibe *et al.* (2007) for Ethiopian goat breeds. However, lower rib-eye area values have been reported by Mesfin (2007) for Arsi-Bale goats. The increased values for the rib-eye area in the present study may suggest that supplementation of low quality roughages such as natural grass hay with MSL has improved the body weight of the goats as the rib-eye measurement and body weights are positively correlated traits.

The values pertaining to the weights of the neck, rack and lumbar areas were higher in goats reared on diets supplemented with 220 g MSL. These observations are in accordance with those of Kebede *et al.* (2008) for Arsi-Bale goats reared on diets containing sweet potato vines. In general, the values obtained in this study for heart, lung, head and trotters are higher in goats supplemented with MSL than those of non-supplemented, which might suggest an active body physiological activity of these organs as a result of relatively high intake of MSL with the supplemented diets.

4.3 Chemical composition of the meat and its quality

The contents of protein and fat were found to be significantly higher in the meat from goats fed on diets supplemented with the 170 and 220 g MSL than those reared on the control diets (Table 6). The study conducted by Qwele *et al.* (2013) indicated that the *M. oleifera* leaf had the antioxidative potential which was responsible for improving meat quality (chemical composition, colour and lipid stability) of goats. The *Moringa stenopetala* leaf extract have been also reported to contain an antioxidant fraction (Tebeka & Libsu, 2014), which might be responsible for enhanced protein and fat contents observed in goats supplemented with MSL. It has been suggested that these antioxidant compounds may also assist in the prevention of meat degradation by oxidation (Moyo *et al.*, 2011, 2012).

To the authors' knowledge, no literature data for Ethiopia are available to compare the chemical composition of local goat meat. Thus, comparisons were made among goats reared in other tropical countries. The chemical composition values of the meat obtained from the present study are consistent with those reported by Kadim *et al.* (2004) for the Omani goat, Babiker & Bello (1986) for the Desert goat, and Agnihotri *et al.* (2006) for Barbari goats. The CP and fat contents of the meat of goats fed on the control and 120 g MSL supplemented diets were comparable to those reported by Agnihotri *et al.* (2006).

The meat pH values in the current study are consistent with the findings of Kannan *et al.* (2001) for Spanish goats (5.96) and Kadim *et al.* (2004) for the Omani goats (5.78). However, pH values of the meat in the present study are lower than those reported by Marinova *et al.* (2001) for Bulgarian White goat. The differences between breeds, treatment diets and also the muscle fibre proportions (red or white) might explain these differences as suggested by Kannan *et al.* (2001).

Increased cooking loss percentage is a reflection of the decreased water-holding capacity (increased expressed juice) associated with meat of high ultimate pH (Bouton *et al.*, 1971). The cooking loss percentage values across the treatment diets are within the normal range for goat muscles and are in good agreements with those of Babiker *et al.* (1990) and Das & Rajkumar (2010). However, Kannan *et al.* (2001) reported lower values for these parameters which might be attributed to the age of the studied goats themselves. The ash content of the meat did not vary across the treatments and is comparable with the results reported by Agnihotri *et al.* (2006).

5 Conclusion

The supplementation with *M. stenopetala* leaf of young Arsi-Bale male goats has considerably improved body weight gains, many carcass traits as well as meat quality as compared to the non-supplemented group. Moreover, the supplementation of *M. stenopetala* leaf enhanced the protein and ether extract content of the goats indicating a better retention of these nutrients. Consequently, supplementation with Moringa leaf is a viable option for improving the productivity of livestock particularly that of small ruminants under smallholder farming conditions where conventional protein supplementation of low quality local feed resources are not accessible and affordable.

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