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Full Length Research Paper

Slaughter performance and meat quality of intact and castrated Washera sheep kept under feedlot condition

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A study was conducted to evaluate the feedlot performance in carcass traits and meat quality of intact and castrated Washera sheep under low (300 g/day) and high (450 g/day) dry matter (DM) levels of concentrate mix supplementation. The concentrate mix contained 68% wheat bran and 32% noug seed cake. 24 sheep (12 intact and 12 castrated) with age range of 9 to 10 months and initial weight of 24.1±1.8 kg (mean ± SD) were used. A randomized complete block design in a 2x2 factorial treatment arrangement (2 sex category and 2 concentrate levels) was employed. Basal hay was fed *ad libitum* at a rate of 20% refusal. After 90 days of fattening, all sheep were slaughtered and meat sample from *longissimus dorsi* muscle of each animal was taken for color and pH measures, and chemical composition analysis. High level supplementation promoted significantly (p<0.001) higher carcass weights, dressing percentage in slaughter body weight (SBW) basis, rib eye-muscle (REM) area, fat thickness (FT), carcass compositions and higher (p<0.05) total edible offal component than low supplementation level. Intact sheep attained higher (p<0.05) SBW (29.4 vs 28.2 kg); empty body weight (23.7 vs 22.9 kg), and produced relatively more carcass yield with higher (p<0.001) muscle, but lower fat composition than castrates. Castrated sheep produced significantly (p<0.01) higher total non carcass fat (0.65 vs 0.46 kg) than intact sheep. Meat from intact sheep comprised of higher (p<0.01) moisture (73.63 vs 72.43%) with lower fat composition (2.06 vs 3.16%) and was less (p<0.05) luminous (L*) in color (34.56 vs 36.63) than castrated sheep. It is concluded that fattening of intact Washera sheep with high level of concentrate supplementation is a better option for production of more carcasses yield with higher proportion of muscle and less fat.

Key words: Carcass composition, dressing percentage, meat color, proximate compositions.

INTRODUCTION

Meat production is the most important function of sheep in Ethiopia. As a result the demands for meat from sheep in the country particularly during religious festivals are very high (Amha, 2008). Farmers usually try to manipulate growth of small ruminants through several means such as breeding, nutrition, and castration to increase meat production and maximize income.

Castration is an important on-farm management practice performed by sheep producers in Ethiopia. The prominent reasons for castration include reducing

aggression and sexual activity, easier and safer handling, management flexibility to finish lambs to meet market specifications under variable seasonal conditions, and more importantly for the production of improved meat quality related to carcass composition and weight development (Alemu, 2008; Sheep Standards and Guidelines Writing Group (SSGWG), 2013).

However, the appropriate age of castrating sheep for fattening in Ethiopia appears not to be clearly defined (Getachew and Wamatu, 2014). Ideally, castration should be done at the youngest age possible, usually less than 3 weeks of age (Alemu, 2008); if it is late, before 12 weeks old (SSGWG, 2013) as the stress of castration can adversely affect growth in older animals. But, under Ethiopian conditions this is not usually the case and many farmers prefer to castrate male sheep at a later age; in most cases after sexual maturity is attained, mainly from yearling to 2 years old (Alemu, 2008). Similarly, Washera sheep producing farmers in Northwestern Ethiopia believe that rams mature, finish their growth and fetch good price when they are castrated at the late age (Mengistie et al., 2010).

Apart from the big variations among different meat animal species in the production of carcass yield or dressing percentage and quality of meat, there is also gender effect (male, female and castrate) which is mainly related to the quantity of fat deposited, deposition site, growth rate and carcass yield (Guerrero et al., 2013).

Many studies have been published in relation to carcass characteristics of various indigenous sheep breeds in Ethiopia mainly for growing male sheep. Despite the very long traditional activity of sheep producing society in castrating sheep and fattening for economic and social values in Amhara region (Mengistie et al., 2010; Yenesew et al., 2013), no comparative performance evaluation study between intact and castrated Washera sheep is available. Therefore, the present study was designed to fill this gap with the objectives of evaluating the difference in carcass and non-carcass characteristics, and meat quality of intact and castrated Washera sheep kept under feedlot condition.

MATERIALS AND METHODS

The study area

The study was conducted at Burie, Debre Markos University campus, which is situated at latitude 10°42' North and longitude 37°4' East and at an altitude of 2091 meters above sea level. The area features a semi-humid climate with relatively cool temperatures. The average minimum and maximum annual temperature of the area are 14 and 24°C, respectively. It has uni-modal rainfall pattern with annual precipitation of 1000 to 1500 mm, the bulk of which occurs from May to September (IPMS, 2007).

Experimental animals and managements

A total of 24 male Washera sheep of about 8 to 10 months of age were purchased from the local market and used for the experiment. The age of the animals was estimated by the pattern of eruption of the incisor teeth (Solomon and Kassahun, 2009), and the information obtained from the owners.

In the experimental site, the sheep were quarantined for 21 days in order to observe their health condition, and vaccinated for sheep pox and injected with 20% oxy-tetracycline for treatment of Pasteurellosis. Ivermectin was injected as a broad spectrum treatment against internal and external parasites. They were also de-warmed with Albendazole mainly against the adult stages of internal parasites. During the third week of the quarantine period, twelve of the twenty four rams were castrated using Burdizzo clamp method. Then all animals were left grazing for about 45 days to help the castrated animals recover from the stress of castration.

After the recovery period, sheep within the same sex were blocked into six groups of two sheep each based on their initial weights and randomly assigned to treatments (six animals per treatment) and well-ventilated individual pens equipped with watering and feeding troughs. The sheep were acclimated to the pen environment and experimental condition for about two weeks, which was followed by 90 days of fattening/feeding trial.

Experimental design and treatments

The experiment was arranged in a randomized complete block design with 2×2 factorial arrangements (two sex categories (castrated and intact sheep) and two concentrate levels). The experiment feeds consisted of mixed sward natural pasture hay as a basal diet and concentrate mix as a supplement. The hay was manually chopped to about 2.5 cm sizes and fed *ad lib* ensuring a refusal of 20%, and the amount of offer was adjusted once every third day. Animals were supplemented with either low (300 g DM/day/head) or high (450 g DM/day/head) level of concentrate mix. The concentrate diet was introduced gradually over the two weeks of acclimation period until the total daily offer reached the end of the acclimation period.

The levels of concentrate were designed on the basis of recommended levels used in earlier works to evaluate fattening potential of Washera sheep (Tesfaye et al., 2011). The concentrate mix composed of 68% wheat bran (WB) and 32% noug seed cake (NSC) and was formulated to have about 22% crude protein (CP) (Table 1) to fulfill the nutrient requirements of growing lambs based on the recommendations by Kearl (1982). The concentrate was offered twice a day in two equal portions at 0800 and 1600 h. Clean water and salt lick were available all the time throughout the experimental period.

Slaughter of animals and carcass measurements

At the end of the 90 days fattening period, all animals were

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Table 1. Chemical composition (% for DM and % of DM for others) of experimental feeds.

Experimental feed	DM	OM	Ash	CP	NDF	ADF	ADL
Hay	92.1	90.0	10	7.9	72.2	46.5	10.1
Wheat bran (WB)	90.8	89.7	10.3	18	44.1	14.4	8.1
Noug cake (NSC)	92.2	91.9	8.1	31.8	34.9	28.2	10.9
Concentrate mix	90.9	91.7	8.3	21.6	41	15.5	8.7

Note: DM = Dry matter; OM = Organic matter; CP = Crude protein; NDF = Neutral detergent fiber; ADF = Acid detergent fiber; ADL = Acid detergent lignin; Concentrate Mix = 32% NSC + 68% WB.

withdrawn from feed overnight with free access to water, and slaughtered after recording slaughter body weight (SBW). The blood was drained into a bucket and weighed. After the removal of digestive tract and non-carcass components, hot carcass weight (HCW) was recorded including tail fat.

Edible and non-edible offal components and all non-carcass fat depots (kidney, omental and mesenteric fats) were weighed and recorded. The weight of the digestive tract was recorded while full and empty thus, weight of gut-content was computed as the difference between digestive tract weights while full and empty. Empty body weight (EBW) was determined as SBW less gut contents. Dressing percentage (DP) was calculated as (HCW/SBW)*100 and (HCW/EBW)*100. Rib eye-muscle area (REM) and fat thickness (FT) were measured at the 12/13th rib position using transparent paper and plastic ruler, respectively.

The left and right REM area were traced onto a square paper which was placed on the transparency, and the area of the squares (0.25 cm^2 each) that fell within the traced area was measured and those partially outside was estimated; thus the average of the two sides was taken as the REM area. After the tail of each carcass was removed and recorded, the whole carcass was split into two halves (left and right) along the dorsal mid-line with a band saw, and the left half of each carcass was kept in a cold (4 to 5°C) room for 24 h. The cold carcass weight (CCW) was recorded for each and dissected into muscle, bone and fat (subcutaneous and intermuscular) to determine carcass composition. Water loss of the carcass was determined as shrink loss.

Chemical analysis of feed

Representative samples of feeds and hay refusals were dried at 60°C for 72 h. The dried samples were ground using laboratory mill to pass through 1 mm screen, and stored for subsequent analyses of dry matter (DM), crude protein (CP), ash (AOAC, 1990), acid detergent fiber (ADF), neutral detergent fiber (NDF) and acid detergent lignin (ADL) (Van Soest and Robertson, 1985). The CP was calculated as N*6.25.

Proximate chemical analysis of meat

Meat samples were taken from longissimus dorsi muscle (LDM) at 10 to 13th rib positions, chopped and thoroughly mixed and frozen at -20°C until partially dried. The frozen fresh samples were partially dried at 55°C for 72 h, packed in polyethylene bags and stored in a refrigerator at 4°C pending proximate chemical analysis. About 2 g of partially dried samples were weighed into a pre-weighed crucible dish, and dried in an oven at 102°C overnight to determine percentage of DM. Ashing was carried out at 600°C for 6 h. Total fat was extracted using Soxhlet apparatus for 6 h with diethyl ether (boiling point of 34.5°C), and the dried residue was weighed for fat content. Crude protein was determined by Kjeldahl procedure (AOAC, 1990).

Meat pH and color measurements

Trimmed meat samples taken from areas of LDM for proximate composition analysis were used for pH and color measurements. The pH measurements were made 1 and 24 (ultimate) h after slaughter using portable pH-meter (Meat PH meter-HI99163, HANAN instruments) having sharp penetrating electrode. The probe was cleaned with distilled water and calibrated with pH 4.1 and 7.1 standard buffer solutions between sample measurements. For met color measurements, the cut surface of frozen samples at 4°C were freshly exposed on flat surface of white background in the measuring room, and allowed to bloom for about 30 to 45 min at ambient temperature. Then, meat color parameters that is, CIE L*a*b* values (L*=lightness, a*=redness and b*=yellowness) were obtained using the digital colorimeter (HunterLab MiniScan EZ, Serial No. MsEZ1547, 45/0^o illumination/viewing system, D65 light source, and 10° observer angle) calibrated with black and white standardized calibration plates between sample measurements (AMSA, 2012). Three random readings at different locations per sample were taken and averaged.

Statistical analysis

Data was analyzed using the general linear model GLM procedure of SAS (SAS, 2003). Adjusted Tukey test was used to locate the significant differences between means when F-test declare significance at $p<0.05$. The statistical model used was:

$Yijkl = \mu + Bi + Sj + Ck + (S\times C)jk + \varepsilon l$.

Where: Yijkl = the response variable; μ = overall mean; Bi = effect of block; Sj = effect of sex; Ck = effect of concentrate level; (S×C)jk = interaction between sex of sheep and concentrate level, and εl = random error.

Since interaction between sex and concentrate level for all attributes evaluated were not statistically significant ($p>0.05$), only means for main effects were presented and discussed.

RESULTS

Carcass yield and carcass characteristics

Intact sheep had about 4% higher ($p<0.05$) SBW and EBW than castrates, but there was no difference ($p>0.05$) in HCW and CCW weights, DP and other carcass attributes between the two sex (Table 2). Unlike sex effect, almost all carcass characteristics were significantly

Table 2. Carcass yield and carcass characteristics of intact and castrated Washera sheep fed grass hay basal diet supplemented with two levels of concentrate mix.

Parameter	Sex category (S)			Concentrate level (C)			SEM
	Intact	Castrate	p-value	Low	High	p-value	
Number of sheep	6	6	-	6	6	-	-
SBW (kg)	29.4[a]	28.2[b]	0.008	28.1[b]	29.5[a]	<.001	0.27
EBW (kg)	23.7[a]	22.9[b]	0.028	22.5[b]	24.1[a]	<.001	0.24
HCW (kg)	12.7	12.3	0.257	12.0[b]	13.1[a]	0.001	0.19
CCW (kg)	12.2	11.8	0.271	11.5[b]	12.5[a]	0.001	0.18
Shrink (kg)	0.53	0.51	0.10	0.49[b]	0.55[a]	<.001	0.01
Dressing percentage							
EBW basis	53.3	53.9	0.463	53.2	54.0	0.266	0.54
SBW basis	43.1	43.8	0.288	42.7[b]	44.2[a]	0.019	0.44
REM area (cm^2)	9.9	8.6	0.051	8.4[b]	10.3[a]	0.002	0.40
FT (mm)	5.2	5.3	0.710	4.9[b]	5.5[a]	0.003	0.12

[a,b]Means with different superscript letter within sex category and diet in the same row differ significantly (p<0.05); Low = 300 g/d concentrate mix; High = 450 g/d concentrate mix; SEM = Standard error of mean; SBW = Slaughter body weight; EBW = Empty body weight; HCW = Hot carcass weight; DP = Dressing percentage; FT = Fat thickness; REM = Rib eye muscle.

Table 3. Carcass composition of intact and castrated Washera sheep fed grass hay basal diet supplemented with two levels of concentrate mix.

Parameter	Sex category (S)			Concentrate level (C)			SEM
	Intact	Castrate	p-value	Low	High	p-value	
Carcass composition (kg)							
Muscle	6.85[a]	6.12[b]	0.002	6.41	6.56	0.499	0.15
Fat	1.45[b]	1.66[a]	0.002	1.44[b]	1.67[a]	0.001	0.04
Bone	2.89[b]	3.08[a]	0.001	2.73[b]	3.13[a]	<.001	0.05
Tail fat	1.0	0.99	0.943	0.89[b]	1.11[a]	0.022	0.06
Carcass composition (%)							
Muscle	56.7[a]	51.7[b]	<.001	52.6[b]	55.8[a]	<.001	0.41
Fat	11.6[b]	13.9[a]	<.001	12.5[b]	13.4[a]	0.003	0.17
Bone	23.3[b]	25.9[a]	<.001	23.8[b]	25.1[a]	<.001	0.21
Tail fat	8.3	8.5	0.840	7.9[b]	8.9[a]	0.015	0.49

[a,b]Means with different superscript letter within sex category and diet in the same row differ significantly (p<0.05); Low = 300 g/d concentrate mix; High = 450 g/d concentrate mix; SEM = Standard error of mean.

(p<0.01) affected by supplement levels. Sheep that consumed high level of concentrate supplement had heavier carcass (HCW and CCW) weights, were better in DP on basis of SBW, and had higher REM and FT than those supplemented in the low level.

Carcass composition

The effects of sex and concentrate level were significant for majority of the carcass composition parameters (Table 3). Carcasses obtained from sheep that consumed high level of concentrate had higher (p<0.01) fat, bone and tail fat weight. When computed on percentage basis, all carcass compositions were higher (p<0.001) for high concentrate level. On the other hand, intact sheep had significantly (p<0.01) higher muscle, but lower fat and bone compositions.

Edible and non-edible offal components

Among edible offal components, blood and intestine were higher in intact than castrates, while fats from omental and mesenteric areas, and total non-carcass fat (TNCF) were higher (p<0.01) for castrates (Table 4). Heart,

Table 4. Edible offal components of intact and castrated Washera sheep fed grass hay basal diet supplemented with two levels of concentrate mix.

Edible offal (kg)	Sex category (S)			Concentrate level (C)			SEM
	Intact	Castrate	p-value	Low	High	p-value	
Blood	1.15[a]	1.02[b]	0.049	1.05	1.12	0.256	0.04
Heart	0.11	0.12	0.254	0.10[b]	0.12[a]	0.002	0.01
Kidney	0.07	0.08	0.215	0.06[b]	0.08[a]	0.027	0.01
Liver	0.41	0.38	0.380	0.33[b]	0.46[a]	0.002	0.03
Empty Stomach	0.74	0.73	0.660	0.71[b]	0.76[a]	0.019	0.01
Intestine	0.74[a]	0.68[b]	0.018	0.68[b]	0.74[a]	0.033	0.02
Head & tongue	1.59	1.48	0.208	1.55	1.53	0.812	0.07
Heart fat	0.04	0.05	0.359	0.04	0.05	0.124	0.01
Kidney fat	0.07	0.09	0.367	0.08	0.07	0.518	0.01
Omenetal fat	0.12[b]	0.21[a]	0.001	0.15	0.16	0.770	0.01
Mesenteric fat	0.17[b]	0.24[a]	0.007	0.20	0.21	0.696	0.02
TNCF	0.46[b]	0.65[a]	0.002	0.54	0.57	0.625	0.04
TEO	5.21	5.04	0.252	4.97[b]	5.28[a]	0.046	0.10

[a,b]Means with different superscript letter within sex category and diet in the same row differ significantly ($p<0.05$); Low = 300 g/d concentrate mix; High = 450 g/d concentrate mix; SEM = Standard error of mean; TNCF = Total non carcass fat; TEO = Total edible offal.

Table 5. Non-edible offal components of intact and castrated Washera sheep fed grass hay basal diet supplemented with two levels of concentrate mix.

Non-edible offal (kg)	Sex category (S)			Concentrate level (C)			SEM
	Intact	Castrate	p-value	Low	High	p-value	
Lung	0.25	0.24	0.557	0.23[b]	0.26[a]	0.007	0.01
Trachea	0.08	0.10	0.065	0.08	0.10	0.051	0.01
Esophagus	0.04	0.05	0.374	0.04	0.05	0.142	0.003
Spleen	0.07[a]	0.05[b]	0.003	0.05[b]	0.07[a]	0.003	0.003
Testicle	0.36[a]	0.15[b]	<.001	0.23[b]	0.27[a]	0.027	0.012
Penis	0.06[a]	0.04[b]	<.001	0.05	0.05	0.936	0.004
Skin and legs	3.77[a]	3.43[b]	0.019	3.58	3.62	0.751	0.089
Gut content	5.61	5.26	0.200	5.53	5.34	0.496	0.186
TNEO	10.26[a]	9.35[b]	0.005	9.82	9.79	0.904	0.188

[a,b]Means with different superscript letter within sex category and diet in the same row differ significantly ($p<0.05$); Low = 300 g/d concentrate mix; High = 450 g/d concentrate mix; SEM = Standard error of mean; TNEO = Total non-edible offal.

kidney, liver, empty stomach and intestine produced from sheep consumed high level concentrate were heavier than sheep fed low level ($p<0.05$). Although the effects of concentrate levels on the weight of individual edible offal components were inconsistent, total edible offal (TEO) was higher for sheep that consumed high level of concentrate. As depicted in Table 5, the effect of sex was found to be significant for some of non-edible offals (spleen, testicle, penis and skin and legs) and TNEO ($p<0.01$), where intact sheep had higher values than castrates. On the other hand, level of supplement affected ($p<0.01$) the weights of lung, spleen and testicle with higher values for the high level of supplement. The weight of trachea tended to be higher for castrate ($p=0.065$) with high supplement level ($p=0.051$).

Proximate chemical composition of meat

There were significant ($p<0.01$) variations between meat from castrate and intact sheep in its moisture and fat contents (Table 6). Meat from intact sheep had 1.2% higher proportion of moisture, but 1.1% lower fat concentrations than castrates. Concentrate level did not have a significant effect ($p>0.05$) on the proximate composition of meat. But, the ash content of meat from

Table 6. Proximate composition (%) of muscle from intact and castrated Washera sheep fed grass hay basal diet supplemented with two levels of concentrate mix.

Parameter	Sex category (S)			Concentrate level (C)			SEM
	Intact	Castrate	p-value	Low	High	p-value	
Moisture	73.63[a]	72.43[b]	0.008	72.98	73.08	0.809	0.29
CP	20.14	20.53	0.374	20.12	20.56	0.324	0.31
Fat	2.06[b]	3.16[a]	<.001	2.62	2.61	0.959	0.15
Ash	1.89	1.83	0.713	2.04	1.69	0.063	0.12

[a,b]Means with different superscript letter within sex category and diet in the same row differ significantly (p<0.05); Concentrate mix = 32% Noug seed cake + 68% wheat bran; Low = 300 g/d concentrate mix; High = 450 g/d concentrate mix; SEM = Standard error of mean; CP = Crude protein.

Table 7. Color and pH measures of muscle from intact and castrated Washera sheep fed grass hay basal diet supplemented with two levels of concentrate mix.

Parameter	Sex category (S)			Concentrate level (C)			SEM
	Intact	Castrate	p-value	Low	High	p-value	
			Meat color				
L*	34.56[b]	36.63[a]	0.027	35.39	35.79	0.646	0.61
a*	12.45	11.78	0.075	12.46	11.77	0.069	0.25
b*	10.15	10.30	0.682	10.44	10.01	0.248	0.26
			Meat pH				
pH_1	6.33	6.29	0.678	6.32	6.30	0.792	0.06
pH_{24}	5.49	5.43	0.311	5.48	5.44	0.328	0.04

[a,b]Means with different superscript letter within sex category and diet in the same row differ significantly (p<0.05); Low = 300 g/d concentrate mix; High = 450 g/d concentrate mix; SEM = Standard error of mean; L* = lightness index, a* = redness index; b* = yellowness index; pH1 = pH measure taken one hour after slaughter; pH_{24} = pH measure taken 24 hours after slaughter.

sheep supplemented high level of concentrate tended to be higher (p=0.063) compared with those supplemented low level.

Color and pH measures of meat

Average of meat color parameters were 35.59 for L* (measure of lightness), 12.11 for a* (measure of redness) and 10.22 for b* (measure of yellowness) with mean ultimate pH of 5.46. Neither sex nor level of supplementation affected a*, b* and meat pH (Table 7). Meat from castrates was lighter (p<0.05) than that from intact sheep. The intact sheep (p=0.075) and sheep consumed low level of supplement (p=0.069) produced meat that tend to be red in color.

DISCUSSIONS

Slaughter and carcass characteristics

The higher SBW and the relatively better carcass yield of intact than castrated sheep in the present study could be related to the production of testosterone hormone that favored better growth and muscle development in intact sheep (Ismail, 2006).

Nasr et al. (2011) reported faster growth and heavier carcass for intact lambs than castrates or females of same age and under similar management. A comparative study on Dorper lambs also confirmed that intact males attained heavier slaughter body weight and produced relatively more carcass yield than ewes and castrates (Cloete et al., 2012).

In agreement with the present finding, improvement in SBW, HCW, DP and related carcass traits of indigenous sheep with increasing level of supplementation was reported (Awet and Solomon, 2009), which could be attributed to the increased available nutrients for muscle development and better carcass yield.

Tesfaye et al. (2011) noted that carcass weight and related carcass traits of Washera sheep improved with increased level of concentrate supplementation up to 500 g/day. The higher FT and larger REM area recorded from sheep consumed high level supplement reflected the positive relationship between the amount of nutrients

availability and the degree of fat deposition and muscle development. A REM area of 7.3 cm^2 (Berhanu et al., 2014), 12.2 cm^2 (Tesfaye et al., 2011) and a FT of 6.9 mm (Tesfaye et al., 2011) were also reported for the same breed of sheep under different amount of supplement and feeding regimes.

Regardless of the variations between supplement levels, the average DP value on SBW basis fall within the range of 40 to 50% recorded for many tropical sheep breeds (Payne and Wilson, 1999). However, the DP values calculated on SBW and EBW basis were higher than the values (32.7 and 48.2%) reported for the same breed in another study (Berhanu, 2014).

The variations in DP of the same breed at different supplements clearly showed plain of nutrition to have a positive effect on carcass yield as described by Payne and Wilson (1999). The lack of significant difference in DP regardless of the variation in SBW and EBW between sex groups is because of the higher amount of total non-carcass components in intact sheep. Earlier studies also noted increased non-carcass component for intact Afar sheep consuming high level of concentrate (Awet and Solomon, 2009).

Carcass composition

The ideal carcass of meat animals can be described as the one that has a minimum amount of bone, a maximum amount of muscle and an optimum amount of fat (Amha, 2008). The higher proportions of muscle, fat and bone recorded in sheep consumed high level concentrate was presumably a consequence of higher nutrient intakes (Mudalal et al., 2014). The higher proportion of muscle in carcass of intact sheep could be related to testosterone hormones production, which is responsible for favouring nutrient utilization for better growth and masculine body development than deposition of body fat (Ismail, 2006). In agreement with the present finding, Mahgoub et al. (1998) reported that intact male lambs produced highest proportion of lean, lowest proportion of non-carcass and carcass fat than other sex groups. Conversely, the higher proportion of carcass fat in castrated sheep could be attributed to the fact that castrated animals tend to disburse proportionally much energy in fat deposition than muscle development (Alemu, 2008).

Edible and non-edible offals

In different areas of the world, various offal components of meat animals including blood are edible and saleable, and fetch extra money that could add value to the carcass. Ewnetu et al. (1998) noted that in almost all parts of Ethiopia, yield of offal components are important, and it is common to find dishes exclusively made from these items. The increased weight of functional organs and TEO at high level of supplementation in the present study indicated that improving the nutritional status of the animal has a positive impact on the development of such organs and edible offal components proportional to the increased body weight (Archimede et al., 2008). However, the lack of significant differences in most of the individual and TNEO components between supplement levels of the present study agrees with the results of Hirut et al. (2011) who reported that the supplementation has no impact on majority of individual and TNEO components. Similarly, the increased weights of testicle, penis and TNEO of intact sheep might be attributed to the positive impact of male sex hormones on the development of such tissues. This agrees with the results of Awet and Solomon (2009) who reported lower genital organ weight in castrates than intact Afar sheep.

Chemical composition of meat

According to Moran and Wood (1986), meat composition is an important aspect of meat quality and is normally assessed by the amount of physical dissected tissues or chemical analyzed constituents. The lower intramuscular fat concentration of meat produced from intact sheep is associated with an increased moisture concentration. This is in line with the fact that there is an inverse relationship between fat and moisture concentrations of carcass (Stankov et al., 2002). The average moisture, CP, fat and ash contents of the sheep meat in the present study is in line with the 75% water, 19% protein, 2.5% lipid and 0.65% ash contents of sheep meat (Amha, 2008). Mohammad et al. (2013) reported 76.2% moisture, 17.79% protein, 3.02% fat and 1.22% ash contents for sheep aged greater than 6 months and 75.12% moisture, 18.31% protein, 3.91% fat and 1.33% ash content for yearling sheep. The differences in chemical constituents of meat between studies are related to feed type and feeding regime (Guerrero et al., 2013), animals age, breed and sex differences (Shija et al., 2013).

Color and pH of meat

Meat color is an important appearance quality trait as it is the first factor seen by the consumer, and is used as an indication of freshness and wholesomeness (Joo et al., 2013). The higher L* value recorded as a measure of lightness in meat of castrates than intact sheep in the present study could be an attribute of the more intramuscular fat content that makes the meat luminous (Amha, 2008). The present finding agreed with the results obtained by Vnucec et al. (2014) who reported the effect of sex of sheep on L*, but not on pH values and a* and b* measures.

The average L* value (35.6) of sheep meat, regardless

of sex category, in the present study is comparable with the value of 36.4 reported for fat-tail Arsi-Bale sheep, but lower than the 37.2 reported for Black head Ogaden sheep of Ethiopia (Girma et al., 2010). Amha (2008) noted that meat color can be affected by several factors such as species/breed, age, sex, cut of meat, surface drying of the meat and surface spoilage, muscle pH and diet of the animal.

Comparing the meat color measures reported for exotic breeds of sheep, the L* value in the present study is lower than the results reported by different researchers (Craigie et al., 2012; Vnucec et al., 2014). In terms of meat quality, the present color value show that the meat produced is fitted into the values with lightness L* ≥ 34 and redness a* ≥ 9.5 considered as acceptable appearance by average consumers (Khliji et al., 2010).

The average ultimate pH value in the present study was in the range of 5.4 to 5.7 considered as good quality meat (Amha, 2008; Chulayo and Muchenje, 2013). The result is also within the ultimate pH range of 5.49 to 5.86, which is considered as normal (Arguello et al., 2005). Thus, the present finding indicated that the animals were in good physical condition with sufficient glycogen reserve at slaughter for the normal glycolysis process and the associated increase in lactic acid production (Chulayo and Muchenje, 2013). In terms of meat quality, the present pH measure show that the meat produced is fitted into the ultimate pH value ranged from 5.3 to 5.7 considered as meat with good visual appeal and potentially good eating quality (MSA, 2011).

Conclusion

The present study highlighted that intact Washera sheep produced more carcasses, and less carcass and non-carcass fat than castrates. Intact sheep produced meat that tended to be redder than meat from castrates, which was lighter in color. On the other hand, fattening of Washera sheep with high level of supplementation is recommended for production of more carcasses, and carcass from both sexes had a similar pH value in the normal range.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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