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Effect of Different Varieties of Vetch Hay Supplementation on Carcass Characteristics of Sheep Fed a Basal Diet of Fodder Oat Hay

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Abstract: Three vetch varieties; Gebisa, Lalisa and Abdeta were released from Sinana Agricultural Research Center for their superiority in terms of yield or biomass production, disease resistance, wider adaptation and quality based on chemical analysis. However, the effect of feeding these forages on carcass characteristics of sheep was not evaluated. Therefore, the experiment was conducted using thirty five yearling intact male Arsi-Bale sheep with initial body weight of 21.4±0.6 Kg (Mean± SD) with the objectives of investigating the varietal differences of vetch hay on carcass characteristics of Arsi-Bale sheep and to evaluate the potentials of fodder oat and vetch hay based feeding for sheep fattening. The sheep were blocked into seven blocks of five animals based on their initial body weight and animals within each block were randomly assigned to one of the five treatment diets. The treatment diets were; ad libitum fodder oat hay alone (T1) and ad libitum fodder oat hay supplemented with 350g DM hay of four vetch varieties, namely; Gebisa, Lalisa, Abdeta and *Vicia sativa* for T2, T3, T4 and T5, respectively. After the 21 days of quarantine period and 15 days of acclimatization to the experimental diets and pens the sheep were fed their respective treatments for 90 days. At the endof90 days feed was withheld from all the sheep over night, they were weighed the next morning, and the weight was recorded as slaughter body weight (SBW). Once the slaughter body weight was taken the sheep were slaughtered immediately for carcass evaluation. Slaughter body weight (SBW), hot carcass weight (HCW), chilled carcass weight (CCW), empty body weight (EBW) and rib eye muscle area (REMA) were significantly highest ($P < 0.001$) for T1. The proportion of muscle (61.5-63.9%) and fat (16.1-19.8%) were not significantly different ($P > 0.05$) among treatments, while proportion of bone (18.5-21.0%) was significantly higher ($P < 0.01$) for T1 as compared to T2, T3 and T4. The amount of muscle was significantly highest ($P < 0.001$) for T1. In conclusion, supplementation of Gebisa vetch variety (T2) induced highest carcass parameters of sheep than all other treatments and is therefore, recommended. Moreover, based on the results of the current study it was concluded that fodder oat and vetch hay based feeding is explicitly high potential feeding strategy and effort should be made to introduce and scale up the production of these forages in the farming system.

Keywords: Arsi-Bale Sheep, Carcass, Fodder Oat, Vetch Hay

1. Introduction

Carcass can be defined as dead body of an animal for cutting up as meat. It is comprised of different ratios of muscle, bone and fat. The good quality carcass is the one with high muscle, low bone and moderate fat [1]. Dressing percentage is also the most important carcass quality criteria in ruminants. [2]. Carcass yield of an animal varies with the rate of body weight gain, slaughter body weight and dressing percentage [3].

Dressing percentage is influenced by maturity of the animal, sex, whether the animal is intact or castrated, plane of nutrition and amount of gut content during slaughter [4]. It also depends on exclusion of some offal components while weighing hot carcass [5]. The production of meat from sheep can be enhanced in terms of live weight gains and quality by manipulating the level of energy and protein in the feed [6]. Another author also stressed growth performance and carcass yield of sheep can be enhanced by increasing the amount of energy [7]. Fat is deposited only if surplus nutrients are available.

A significant effect on omental and kidney fat, back fat thickness and rib-eye muscle area for a pre-market supplementary feeding of old Horro ewes has been reported [8]. The work done by other author also showed a significant improvement on most carcass and non-carcass parameters like empty body weight, and hot carcass weight; omental fat and total edible offal component for supplemented ones [9]. Higher improvement for most carcass and non-carcass parameters of supplemented Afar rams than the control ones has been also reported [10]. Another experiment also showed that supplementation with hay of forage legumes; pigeon pea, cowpea and lablab hay resulted in an increase in hot carcass weight, dressing percentage and rib eye muscle area [11].

Three vetch varieties; Gebisa, Lalisa and Abdeta [12] were released from Sinana Agricultural Research Center for their superiority in terms of yield or biomass production, disease resistance, wider adaptation and quality based on chemical analysis. However, the effect of feeding these forages on carcass characteristics of sheep was not evaluated. Therefore, the objective of this study was to investigate the effect of varietal differences of vetch hay on carcass characteristics of Arsi-Bale sheep.

2. Materials and Methods

2.1. Description of the Experimental Area

The study was carried out at Sinana Agricultural Research Center (SARC), found in Bale Zone, South Eastern Ethiopia. Sinana is situated at 07°07' N latitude and 40°10' E longitude with an altitude of 2400 m above sea level. The temperature of SARC varies from 21°C and 9°C. Sinana receives rainfall two seasons per year and the average yearly rainfall is750 to 1000 mm.

2.2. Experimental Feeds Preparation

The experimental feeds, all varieties of vetch and fodder oat were sown according to their respective agronomic practices during the main rainy season (August-December) of the area. The vetch varieties were harvested at 50% flowering, while fodder oat was harvested at heading stage during which they give optimum performance in terms of dry matter yield and nutritive value. The harvested fresh forages were field-cured and stored as hay under a roofed shelter to protect from rain and intense sun light. Feeds enough for the entire experimental period were prepared before the commencement of the experiment. During the feeding period, the oat and vetch hays were chopped to about 3-5 cm in length to make uniform for sampling and easier to be seized by the animals.

2.3. Experimental Animals and Their Management

Thirty-five yearling intact male Arsi-Bale sheep with similar body weight were purchased from nearby markets. The age of the sheep was estimated based on dentition and asking information from the owners of the sheep. The sheep were held in quarantine for 21 days and observed for any health problem. During this time, the sheep were vaccinated against ovine pasteruolosis, anthrax and sheep pox and dewormed against internal and external parasites. The sheep were ear tagged for identification. The animals were placed in an individual pens equipped with a bucket and a feeding trough in a well-ventilated concrete floor experimental barn. The sheep were acclimatized for fifteen days to the dietary treatments to which they were allocated prior to the commencement of the actual experiment by offering them gradually. Pen cleaning was conducted twice per day at 6:00 AM and 6:00 PM.

2.4. Experimental Design and Treatments

Randomized Complete Block Design (RCBD) was used for the study. To minimize the error due to differences in initial body weight, the experimental sheep were blocked into seven blocks of five animals each based on their initial body weight. Sheep within a block were assigned randomly to one of the five dietary treatments which were; *ad libitum* fodder oat hay alone (T1) and *ad libitum* fodder oat hay supplemented with 350g DM hay of the vetch varieties, namely; Gebisa, Lalisa, Abdeta and *Vicia sativa* for T2, T3, T4 and T5, respectively. Gebisa, Lalisa and Abdeta are improved vetch varieties released from Sinana Agricultural Research Center in 2011. *Vicia sativa,* which was used in fifth treatment (T5), is commonly used adapted vetch to highlands of Bale. Sole fodder oat hay (T1) was used as a control treatment to see the effect of supplementation. For fodder oat hay the recently released variety, Bonsa was used. The level of supplementation was fixed by referring to previous works and nutrient requirement of animals.. The basal diet (fodder oat hay) was offered *ad libitum* to all experimental animals based on previous few days' intake at about 15% refusal while the supplementary feeds were offered in two equal meals at 8:00 AM and 4:00 PM in separate feeding troughs. Drinking water and common salt block were freely available to all experimental sheep throughout the experimental period.

Table 1. *Dietary treatments.*

Treatments	Fodder oat hay	Vetch hay supplements (DM g/day)			
		Gebisa	Lalisa	Abdeta	*Vicia sativa*
T1	*Ad libitum*	0	0	0	0
T2	*Ad libitum*	350	0	0	0
T3	*Ad libitum*	0	350	0	0
T4	*Ad libitum*	0	0	350	0
T5	*Ad libitum*	0	0	0	350

2.5. Carcass Parameters

After the 90 days of feeding, feed was withheld from all the sheep over night, they were weighed the next morning, and the weight was recorded as slaughter body weight (SBW). Once the slaughter body weight was taken the sheep were slaughtered immediately for carcass evaluation. The animals were killed by severing the jugular vein and the carotid artery with a knife. On slaughtering, blood was collected in a container, weighed and recorded. The animals were then suspended with head down. The head was detached from the body and weighed. Skin was carefully flayed to avoid attachment of fat and muscle tissues to the skin and then weighed without feet and the feet below fetlock joints were separately weighed and recorded. Empty body weight was calculated as the difference between slaughter body weight and gut fill. The hot carcass weight (HCW) was taken after removing the head, thorax, abdominal and pelvic cavity contents as well as legs below the hock and knee joints.

Offal components were categorized into edible and non-edible according to the culture of the people in the study area. Both edible offal components (EOC) and non-edible offal components (NEOC) were measured separately and added up for calculation of total edible offal components (TEOC) and Total non-edible offal components (TNEOC).

The main carcass was dissected along the vertebral column in to right and left half. The dissected carcass was then put in a deep freeze at -4°C for 24 hours for ease of separating the carcass in to bone, muscle and fat. Chilled carcass weight (CCW) was taken by weighing the frozen carcass. The right part of the frozen carcass was partitioned in to five main primal cuts. The rib eye muscle area was measured by cutting the carcass between 12th and 13th ribs. [13].

2.6. Chemical Analysis

Samples for chemical analysis were ground to pass a 1 mm sieve mesh. Dry matter, ash and N determination were conducted following the recommended methodologies [14]. Neutral detergent fiber (NDF), acid detergent fiber (ADF) and acid detergent lignin (ADL) were also determined by using the standard procedures [15]. Hemicelluloses (HC) and cellulose (Cell) contents were calculated as NDF minus ADF and ADF minus ADL, respectively.

2.7. Statistical Analysis

Data on carcass parameters were subjected to analysis of variance (ANOVA) using the General Linear Model (GLM) procedure of SAS [16] version 9.1. When significant, Least Significant Difference test (LSD) was employed to locate differences between the treatment means.

Data was analyzed using the following model.

$$Y_{ij} = \mu + T_i + B_j + E_{ij},$$

where:

Y_{ij} = Response variable;
μ = Overall mean;
T_i = Treatment effect
B_j= Block effect, and
E_{ij} = Random error.

3. Results and Discussion

3.1. Chemical Composition of Experimental Feeds

The results of chemical analysis of the experimental feeds is given in Table 2. The 8.9% CP content of fodder oat hay used in this study was slightly lower than the 11.5% CP content of the same variety reported when it was released [17]. Although the CP content of fodder oat hay used in this study was lower than previous reports, it was higher than the 7% CP required for microbial protein synthesis in the rumen that can support at least the maintenance requirement of ruminants [18]. The CP content of Abdeta and Lalisa vetch varieties was also lower than the 24.8% and 24.1% CP content of the same varieties, respectively reported when they were released [12]. The same authors reported higher (21.0%) and comparable (20.8%) CP content for *V. sativa* and Gebisa, respectively. The lower CP content of experimental feeds registered in this study might be due to losses of the leaf fractions containing high CP while curing the experimental forages in the field.

The NDF and ADF contents of fodder oat hay used in this study were comparable with 53.9% NDF and 32.7% ADF reported when it was released [17]. The NDF contents of Lalisa, Abdeta and *V. sativa* vetch varieties used for this study was higher than the NDF contents of the same varieties (41.8, 29.3 and 29.9%, respectively) reported when they were released [12]. However, the NDF content of Gebisa was lower than the 40.8% NDF content of the same variety reported by the same authors. The ADF contents of Lalisa, Abdeta and *V. sativa* vetch varieties used for this study were higher than the ADF contents of the same varieties (35.4, 21.6 and 25.7%, respectively) reported when they were released [12]. However, the ADF content of Gebisa was lower than the 32.6% ADF content of the same variety reported by the same authors.

The inconsistency in chemical composition of the experimental feeds used in this study with previous studies might be associated with growth stage of the plant, harvesting season, method of preparation and preservation. Soil fertility on which the forages were grown, plant morphological components mainly leaf to stem ratio and losses of nutrients during hay making which arises from the action of plant and microbial enzymes, chemical oxidation, leaching and mechanical damage are also among factors affecting the chemical composition of feeds [19] and causes for variability in nutrient content between the same species and variety of forage.

Roughage feeds containing NDF values of less than 45% are classified as high quality, those with values ranging from 45 to 65% as medium quality and those with values higher than 65% as low quality [20]. Accordingly, all vetch varieties used in this experiment are categorized as high quality roughages, except Lalisa that contain NDF value of 48.3%, which is a bit above the critical value to categorize it as high quality roughage. Similarly, the 53.7% NDF content of fodder oat hay used in this study categorizes it as medium quality roughage. Even though the vetch varieties used in this experiment were categorized as good quality forages based on their chemical composition, there is a difference in the values among varieties. Gebisa had higher CP content (21.1%) and lower NDF, ADF, hemicellulose and cellulose contents with a value of 36.5, 27.1, 9.4 and 22.1%, respectively. Lalisa had higher NDF, ADF and ADL with a value of 48.3, 36.9 and 7.7% in that order when compared to other vetch varieties considered. This slight variation in chemical composition might have impact on carcass characteristics of the sheep.

Table 2. *Chemical composition of experimental feeds.*

Feed offered	DM%	Ash	OM	CP	NDF	ADF	ADL	HC	Cell
		%DM							
Fodder oat hay	87.2	10.6	89.4	8.9	53.7	30.0	2.7	23.7	27.3
Vetch hay supplements									
Gebisa	87.5	15.0	85.0	21.1	36.5	27.1	5.0	9.4	22.1
Lalisa	87.1	15.7	84.3	19.5	48.3	36.9	7.7	11.3	29.2
Abdeta	86.6	11.9	88.1	18.0	39.6	28.8	4.6	10.8	24.1
V. sativa	87.7	17.9	82.1	18.4	42.1	32.0	6.4	10.1	25.7

ADF=Acid Detergent Fiber; ADL=Acid Detergent Lignin; Cell=Cellulose; CP=Crude Protein; DM=Dry Matter; HC=Hemicelluloses; NDF=Neutral Detergent Fiber; OM=Organic Matter; T1 = Fodder oat hay *ad libitum*; T2 = Fodder oat hay *ad libitum* + 350 g DM/day Gebisa; T3 = Fodder oat hay *ad libitum* + 350 g DM/day Lalisa; T4 = Fodder oat hay *ad libitum* + 350 g DM/day Abdeta; T5 = Fodder oat hay *ad libitum* + 350 g DM/day *V. sativa.*

3.2. Carcass Characteristics

3.2.1. Main Carcass Parameters

Slaughter body weight (SBW), hot carcass weight (HCW), chilled carcass weight (CCW), empty body weight (EBW) and rib eye muscle area (REMA) significantly varied (P<0.001) among treatments and were positively affected by supplementation (Table 3). The higher REMA of supplemented treatments over un-supplemented ones indicates that supplemented sheep were able to develop better muscling than the control. Among supplemented treatments, SBW, HCW and REMA were highest (P<0.001) for T2 and similar (P>0.05) for other treatments. Supplementation of the vetch varieties has increased HCW by 28.2, 9.7, 13.7 and 16.1% for T2, T3, T4 and T5, respectively. Moreover, EBW was also highest (P<0.001) for those sheep supplemented with Gebisa vetch variety (T2) followed by T4=T5, T3 and T1 in that order.

A significant increase due to supplementation in carcass parameters of Wollo lambs fed a basal diet of natural grass hay and supplemented with Pigeon pea, Cowpea and Lablab hay meals was reported [11]. Similarly, several authors reported a significant increase in carcass parameters of sheep as a result of high protein feed supplementation to low quality basal roughages [21-23]. This is obviously due to increased dry matter and nutrient intake and dry matter and nutrient digestibility as a result of supplemental protein [24].

The slaughter body weight (SBW), HCW, CCW, EBW and REMA obtained by supplementation of the vetch varieties in the current study were by far higher than the values previously reported for Arsi-Bale sheep under different feeding regimes [21, 23, 25, 26]. Therefore, the result of the current study strongly showed that fodder oat and vetch hay based feeding for livestock is high potential feeding strategy which should be widely scaled up to farmers and livestock investors.

Table 3. *Main carcass parameters of Arsi-Bale sheep fed a basal diet of fodder oat hay and supplemented with four varieties of vetch hay.*

Parameters	Treatments					SEM	SL
	T1	T2	T3	T4	T5		
SBW (kg)	28.9^{c}	34.7^{a}	31.1^{b}	31.8^{b}	32.9^{b}	0.42	***
HCW (kg)	12.4^{c}	15.9^{a}	13.6^{b}	14.1^{b}	14.4^{b}	0.23	***
CCW (kg)	12.2^{d}	15.7^{a}	13.4^{c}	14.0^{bc}	14.3^{b}	0.23	***
EBW (kg)	23.6^{d}	29.1^{a}	25.3^{c}	26.1^{bc}	27.2^{b}	0.38	***
Dressing percentage							
SBW basis	43.0	45.9	43.7	44.5	43.9	0.41	ns
EBW basis	52.6	54.7	53.7	54.2	53.1	0.32	ns
BFT (cm)	0.3	0.4	0.4	0.4	0.4	0.02	ns
REMA (cm^2)	11.5^{c}	14.9^{a}	12.2^{bc}	12.8^{b}	13.3^{b}	0.27	***

^{a,b,c,d} means with different superscripts in a row are significantly different; *= (p<0.5); *** = (P<0.001); CCW=Chilled Carcass Weight; BFT= Back Fat Thickness; HCW=Hot Carcass Weight; EBW=Empty Body Weight; ns=non-significant; REMA=Rib eye Muscle Area; SBW=Slaughter Body Weight; SEM=Standard Error of the Mean; SL=Significance Level; T1 = Fodder oat hay *ad libitum*; T2 = Fodder oat hay *ad libitum* + 350 g DM/day Gebisa; T3 = Fodder oat hay *ad libitum* + 350 g DM/day Lalisa; T4 = Fodder oat hay *ad libitum* + 350 g DM/day Abdeta; T5 = Fodder oat hay *ad libitum* + 350 g DM/day *V. sativa.*

The dressing percentage both on slaughter and empty body weight basis were not significantly different (P>0.05) among the dietary treatments with the overall mean of 44.2 and 53.7%, respectively. Non-significant value of dressing percentages for Arsi- Bale sheep under different feeding regimes were reported by different authors too [25, 26]. The mean value of dressing percentage as ratio of slaughter body weight (44.2%) in this study was higher than the value of

31.5-37.3% for Arsi-Bale sheep fed different varieties of Faba bean straw with a concentrate mixture at a ratio of 70:30 [26]. However, comparable value of dressing percentage on slaughter weight basis (44.2%) was reported by for Arsi-Bale sheep fed Faba bean haulms as basal diet and supplemented with 300g concentrate mixture of barley bran and linseed meal mixed at a ratio of 1:2 [21]. A comparable value of dressing percentage on slaughter weight basis (41.34, 39.59 and 42.07%) for Wollo lambs fed natural pasture hay+200g wheat bran and supplemented with 243g DM pigeon pea, 260g DM cow pea and 225g DM lablab, respectively was also reported [11].

3.2.2. Edible Offal Components

Edible offal components of Arsi-Bale sheep fed a basal diet of fodder oat hay and supplemented with different varieties of vetch hay are presented in Table 4. Most of the edible offal components in this study were not significantly affected (P>0.05) by treatments except blood, tongue, kidney and total edible offal components.

Table 4. *Edible offal components of Arsi-Bale sheep fed a basal diet of fodder oat hay and supplemented with different varieties of vetch hay.*

Parameters	Treatments					SEM	SL
	T1	T2	T3	T4	T5		
Blood (g)	1102.1^{b}	1357.1^{a}	1317.3^{a}	1199.7^{ab}	1303.7^{a}	26.87	*
Liver (g)	353.9	472.4	415.7	413.3	428.0	13.75	ns
Kidney (g)	84.4^{c}	99.9^{a}	89.6^{bc}	90.4^{bc}	94.3^{ab}	1.50	**
Heart (g)	110.6	132.4	117.0	115.1	121.1	2.40	ns
Tongue (g)	106.9^{b}	164.7^{a}	100.1^{b}	115.3^{b}	138.0^{ab}	6.70	*
Ret-rum (g)	662.4	766.4	682.1	731.4	764.9	16.66	ns
Om-ab (g)	285.0	259.3	269.4	273.3	281.7	15.98	ns
SI (g)	846.4	975.0	816.9	920.1	898.4	20.76	ns
LI (g)	180.1	156.3	150.4	162.7	175.9	12.81	ns
Testicle	330.7	418.9	362.9	391.3	371.1	9.55	ns
Kidney fat (g)	98.3	168.3	138.0	156.0	140.6	9.48	ns
Heart fat (g)	43.0	63.4	66.1	73.7	50.6	3.77	ns
Omental fat (g)	135.6	286.14	159.7	233.7	208.0	25.68	ns
Scrotal fat (g)	74.6	109.1	79.3	97.4	95.9	4.80	ns
Pelvic fat (g)	42.4	66.7	53.7	62.3	57.0	3.41	ns
TEOC (kg)	4.5^{c}	5.5^{a}	4.8^{bc}	5.0^{abc}	5.1^{ab}	0.10	*

[a,b,c,] means with different superscripts in a row are significantly different; *=(P<0.05); **=(P<0.01); LI=Large Intestine; ns=non-significant; Om-ab=Omasum-abomasum; Ret-rum=Reticulo-rumen; SEM=Standard Error of the Mean; SI=Small Intestine; SL=Significance Level; TEOC=Total Edible Offal Component; T1 = Fodder oat hay *ad libitum*; T2 = Fodder oat hay *ad libitum* + 350 g DM/day Gebisa; T3 = Fodder oat hay *ad libitum* + 350 g DM/day Lalisa; T4 = Fodder oat hay *ad libitum* + 350 g DM/day Abdeta; T5 = Fodder oat hay *ad libitum* + 350 g DM/day *V. sativa.*

The result of the current study revealed that weight of the majority of offal components (organs) did not vary among sheep of the same breed, age and sex though their body weight and other main carcass parameters differ as a result of varying feeding regimes. Previous reports indicated that differences in internal organs are more influenced by age, breed and sex of the animals rather than plane of nutrition, which support the current result [27]. Moreover, other authors also reported that the weight of offal components was not significantly affected by different feeding regimes [25, 26]. The weight of blood was significantly higher (P<0.01) for T2, T3 and T5 than T1. This might be associated with slaughter body weight of the animals as T2, T3 and T5 had significantly higher slaughter body weight than T1. Other authors also reported significantly higher weight of blood for sheep of higher SBW than sheep with lower SBW [21, 22]. This suggests that the blood volume of animals is proportional to body mass of the animal. Kidney weight was significantly higher (P<0.01) for T2 as compared to T1, T3 and T4. Similarly, the weight of tongue was significantly higher (P<0.05) for T2 than T1, T3 and T4. The significantly higher kidney and tongue weight of T2 than T1, T3 and T4 might be also associated with body weight of the animals as sheep in T2 had significantly higher (P<0.001) SBW than sheep in all other treatments. The weight of TEOC significantly differed (P<0.05) among treatments and was positively affected by supplementation of the vetch varieties. Supplementation of Gebisa (T2) and *Vicia sativa* (T5) resulted in significantly higher (P<0.05) TEOC than un-supplemented treatment (T1). This is because of the higher numerical values and in some significantly higher weights of the different organs (edible offal components) in these treatments as compared to T1.

3.2.3. Non-edible Offal Components

Non-edible offal components of Arsi-Bale sheep fed a basal diet of fodder oat hay and supplemented with different varieties of vetch hay are presented in Table 5. All non-edible offal components were not significantly differed (P>0.05) across treatments showing that non-edible offal components were not affected by supplementation of the hay of the vetch varieties in this study. This indicates that the treatment difference in this study was unable to bring differences in non-edible offal components. The result of the current study revealed that since the weight of offal components were less affected by plane of nutrition the major objective of supplementing sheep with high protein feeds should be to increase the weight of muscles rather than the weight of offal components.

Previous findings indicated that animals that consumed higher weight of feed with low digestibility had higher gut fill weight at slaughter because of deterred ruminal digestibility of nutrients and increased ruminal retention time [22]. However, in the current study the difference in the weight of gut fill was not significantly differed among treatments. This might be due to the time elapsed (overnight fasting time prior to slaughter) until slaughtering that made to shrink their gut fill equally. However, numerically supplementation of Lalisa vetch variety led to higher gut fill weight among the supplemented treatments. This might be attributed to higher NDF and ADF content of Lalisa vetch variety due to the fact that feeds with high fiber content has low digestibility and retain for longer time in the rumen than feeds with low fiber content [19].

Table 5. *Non-edible offal components of Arsi-Bale sheep fed a basal diet of fodder oat hay and supplemented with different varieties of vetch hay.*

Parameters	Treatments					SEM	SL
	T1	T2	T3	T4	T5		
Head without tongue (g)	1626.4	1789.1	1726.4	1817.4	1822.9	47.50	ns
skin (g)	2360.3	2660.7	2577.9	2599.4	2600.0	44.20	ns
Lung with trachea (g)	384.0	394.1	382.4	377.7	385.4	8.57	ns
Spleen (g)	58.3	57.3	59.4	52.6	54.7	2.40	ns
Pancreas (g)	36.1	39.0	36.6	37.0	42.0	1.22	ns
Bladder (g)	15.6	17.7	12.00	13.7	13.7	1.03	ns
Gall bladder (g)	12.0	8.7	7.6	9.1	8.1	1.14	ns
Penis (g)	58.3	57.3	55.7	54.4	54.6	1.75	ns
Feet with hooves (g)	477.0	523.9	494.0	496.0	509.4	5.68	ns
Gut fill (g)	5290.7	5593.7	5779.6	5721.0	5711.4	189.27	ns
TNEOC (kg)	10.3	11.1	11.1	11.2	11.2	0.21	ns

ns=non-significant; SL=Significance Level; SEM=Standard Error of the Mean; TNEOC=Total Non-edible Offal Component; T1 = Fodder oat hay ad libitum; T2 = Fodder oat hay ad libitum + 350 g DM/day Gebisa; T3 = Fodder oat hay ad libitum + 350 g DM/day Lalisa; T4 = Fodder oat hay ad libitum + 350 g DM/day Abdeta; T5 = Fodder oat hay ad libitum + 350 g DM/day V. sativa.

3.2.4. Proportions of Main Carcass Parameters and Offal Components

The result of this study showed that gut fill to slaughter body weight (GF: SBW), total edible offal components to total non-edible offal components (TEOC: TNEOC), total edible offal components to empty body weight (TEOC: EBW) and total non-edible offal components to empty body weight (TNEOC: EBW) were not significantly different (P>0.05) among treatments (Table 6). Previous studies also indicated nutrition did not significantly affect the proportion of main carcass parameters and offal components, which support the current finding [21, 25]. The proportion of main carcass and offal parameters is subjective due to the absence of consistency in categorizing non-carcass components (offals) into edible and non-edible. They are categorized based on traditional beliefs, culture, and differences in preference of the people from one locality to the other. The proportion of GF: SBW (16.1-18.6%) in this study is lower than the 18-26% reported by other author [21]. Among supplemented groups, supplementation of Lalisa vetch variety resulted in higher GF: SBW, though the difference was not significant. This is attributed to relatively higher GF and lower SBW of those sheep in T3 as a result of higher NDF and ADF content of Lalisa vetch variety due to the fact that feeds with high fiber content has low digestibility and retain for longer time in the rumen than feeds with low fiber content [19]. The absence of significant difference in proportion of GF: SBW might be due to the time elapsed (overnight fasting time prior to slaughter) until slaughtering that made to shrink their gut fill equally. Supplementation of Gebisa has resulted to lower TNEOC: EBW numerically than the other treatments. This might be attributed to better CP and ME energy intake of sheep supplemented with Gebisa, which resulted to higher empty body weight.

Table 61. *Proportions of main carcass parameters and offal components of Arsi-Bale sheep fed a basal diet of fodder oat hay and supplemented with different varieties of vetch hay.*

Proportions (%)	Treatments					SEM	SL
	T1	T2	T3	T4	T5		
GF:SBW	18.2	16.1	18.6	17.9	17.4	0.56	ns
TEOC:TNEOC	43.3	49.7	43.7	46.3	45.8	1.17	ns
TEOC:EBW	18.8	18.9	19.0	19.3	18.9	0.25	ns
TNEOC:EBW	43.9	38.4	44.1	43.0	41.3	0.91	ns

EBW = Empty Body Weight; GF = Gut Fill; ns = not significant; SL = Significance Level; SBW = Slaughter Body Weight; SEM = Standard Error of Means; TEOC = Total Edible Offal Components; TNEOC = Total Non-edible Offal Components; T1 = Fodder oat hay *ad libitum*; T2 = Fodder oat hay *ad libitum* + 350 g DM/day Gebisa; T3 = Fodder oat hay *ad libitum* + 350 g DM/day Lalisa; T4 = Fodder oat hay *ad libitum* + 350 g DM/day Abdeta; T5 = Fodder oat hay *ad libitum* + 350 g DM/day *V. sativa.*

3.2.5. Primal Cuts

Muscle from leg significantly differed (P<0.001) among treatments and was positively affected by supplementation (Table 7). Among supplemented treatments, the highest leg muscle from dissected half carcass (1577.7 g) was obtained from those sheep supplemented with Gebisa vetch variety (T2). Weight of leg muscle of T4 was similar to that of T3 and T5, while that of T3 was similar (P>0.05) to that of T4 and T1. Similarly, muscle from loin and muscle from breast and shank also significantly differed (P< 0.01) among treatments and positively affected by supplementation with the highest value obtained from T2. Moreover, muscle from shoulder and neck significantly differed among treatments (P<0.05) with highest value obtained from T2 and with similar values (P>0.05) among other treatments. However, muscle from rack did not significantly differ (P>0.05) among treatments. The highest leg muscle of the primal cuts obtained from sheep supplemented with Gebisa (T2) might be associated with the highest feed intake and digestibility of those sheep, which resulted in highest growth performance and carcass parameters.

Bone from leg significantly differed (P<0.001) among treatments in the order of T2=T5>T1=T3=T4. Similarly, bone from breast and shank significantly affected by treatments. However, bone from the other three primal cuts were not significantly different (P>0.05) among treatments. Regarding fat from the five primal cuts, fat from leg was significantly different (P<0.05) among treatments and positively affected by supplementation of the varieties of vetch. Likewise, fat from breast and shank was also significantly differed (P<0.001) among treatments in the order of T2=T4=T5>T3=T1. However, fat from the other three primal cuts were not significantly different (P>0.05) among treatments.

Regarding the five primal cuts, leg total significantly differed (P<0.001) among treatments and was positively affected by supplementation. Among supplemented treatments, the treatment supplemented with Gebisa (T2) had highest leg total from the dissected half carcass (2368.6 g). Similarly, loin total also significantly differed (P<0.01) among treatments. The loin total of T2 was significantly higher (P<0.01) than loin total of T1 but similar (P>0.05) with loin total of T3, T4 and T5. Moreover, breast and shank total was significantly different among treatments (P<0.001). The highest value of breast and shank total (895.6 g) was recorded from the treatment supplemented with Gebisa. However, the totals of rack and shoulder and neck were similar (P>0.05) among treatments. The proportion of muscle, bone and fat in individual primal cuts were not significantly different (p>0.05) among treatments except proportion of bone from leg and proportion of fat from breast and shank.

Additionally, this study revealed the presence of highest proportion of muscle in loin compared to other primal cuts whereas breast and shank was shown to the lowest proportion of muscle. Moreover, the lowest proportion of bone was recorded from loin. This conforms with the general knowledge that the carcass from loin is more ideal than the carcass from other primal cuts.

Table 7. *Primal cuts of dissected half carcass of Arsi-Bale sheep fed a basal diet of fodder oat hay and supplemented with different varieties of vetch hay.*

Primal cuts			Treatments					SEM	SL
			T1	**T2**	**T3**	**T4**	**T5**		
Leg	Muscle	G	1219.6^{c}	1577.7^{a}	1277.7^{c}	1321.0^{bc}	1426.6^{b}	30.48	***
		%	65.8	66.6	64.8	65.1	66.7	0.39	ns
	Bone	G	358.0^{b}	412.3^{a}	349.9^{b}	352.4^{b}	406.4^{a}	7.48	**
		%	19.4^{a}	17.4^{b}	17.8^{b}	17.4^{b}	19.1^{a}	0.26	**
	Fat	G	274.0^{c}	378.6^{a}	343.7^{ab}	354.6^{ab}	302.1^{bc}	11.44	*
		%	14.8	16.0	17.4	17.5	14.3	0.48	Ns
Leg total (g)			1851.6^{d}	2368.6^{a}	1971.3^{cd}	2028.0^{bc}	2135.1^{b}	40.54	***
Loin	Muscle	G	368.1^{b}	543.6^{a}	447.7^{ab}	513.3^{a}	481.3^{a}	17.08	**
		%	69.7	91.1	80.7	88.6	76.2	3.56	Ns
	Bone	G	88.6	116.6	95.6	96.0	109.7	3.84	Ns
		%	16.9	14.2	14.4	11.9	14.2	0.65	Ns
	Fat	G	105.4	162.2	130.3	189.1	182.3	9.93	Ns
		%	19.3	19.4	19.2	23.2	23.5	0.88	Ns
Loin total (g)			562.1^{b}	822.1^{a}	673.3^{ab}	798.4^{a}	773.3^{a}	25.75	**
Rack	Muscle	G	539.4	607.0	565.3	595.9	684.6	24.28	Ns
		%	63.8	60.5	61.6	59.8	60.3	0.74	Ns
	Bone	G	197.3	242.6	211.0	221.3	256.4	8.75	Ns
		%	23.1	23.9	23.1	22.3	23.1	0.34	Ns
	Fat	G	114.3	166.1	136.3	177.0	187.6	9.89	Ns
		%	13.2	15.6	15.3	17.9	16.6	0.66	Ns
Rack total (g)			851.0	1015.7	912.6	994.1	1128.6	39.01	Ns
Breast and shank	Muscle	G	341.6^{b}	449.9^{a}	322.7^{b}	325.4^{b}	379.7^{b}	13.65	**
		%	54.3	50.0	51.6	47.1	48.5	0.86	Ns
	Bone	G	146.9^{c}	185.3^{a}	146.4^{c}	153.3^{bc}	176.3^{ab}	4.78	**
		%	23.7	20.8	23.4	22.4	22.6	0.49	Ns
	Fat	G	137.9^{b}	260.4^{a}	160.9^{b}	211.6^{a}	222.7^{a}	10.28	***
		%	22.0^{b}	29.1^{a}	25.0^{ab}	30.5^{a}	28.9^{a}	0.88	*
Breast and shank total (g)			626.3^{c}	895.6^{a}	630.0^{c}	690.3^{bc}	778.7^{b}	24.57	***
Shoulder and neck	Muscle	G	1057.4^{b}	1402.6^{a}	1169.0^{b}	1185.6^{b}	1116.3^{b}	37.79	*
		%	61.3	67.7	62.5	62.5	61.9	0.95	Ns
	Bone	G	391.1	369.0	388.6	370.7	370.6	9.92	Ns
		%	22.7	17.9	20.6	19.6	21.3	0.45	Ns
	Fat	G	275.3	296.0	315.7	341.6	282.9	14.25	Ns
		%	16.1	14.3	17.0	18.0	16.7	0.81	Ns
Shoulder and neck total (g)			1723.9	2067.6	1873.3	1897.9	1769.7	44.38	Ns

^{a,b,c,d} means with different superscripts in a row are significantly different; *=(P<0.05); **=(P<0.01); ***=(P<0.001); ns = not significant; SL = Significance Level; SEM = Standard Error of Means; T1 = Fodder oat hay *ad libitum*; T2 = Fodder oat hay *ad libitum* + 350 g DM/day Gebisa; T3 = Fodder oat hay *ad libitum* + 350 g DM/day Lalisa; T4 = Fodder oat hay *ad libitum* + 350 g DM/day Abdeta; T5 = Fodder oat hay *ad libitum* + 350 g DM/day *V. sativa.*

Mean weight of muscle, bone and fat and their proportions in dissected half carcass of Arsi-Bale sheep fed a basal diet of fodder oat hay and supplemented with different varieties of vetch hay are presented in Table 8. The sum weight of muscle from the dissected half carcass was significantly (P<0.001) affected by supplementation. Supplementation of the vetch varieties increased the amount of muscle by 31.4, 8.6, 11.4 and 17.1% for T2, T3, T4 and T5, respectively, compared to un-supplemented treatment. Among supplemented treatments, the highest amount of muscle from dissected half carcass (4.6 kg) was obtained from those sheep supplemented with Gebisa vetch variety (T2). Likewise, weight of bone and fat from dissected half carcass were also significantly different (P<0.05) among treatments. The mean weight of bone varied in the order of T2=T5>T1=T3=T4. The mean weight of fat for T2 was similar (P>0.05) to that of T3, T4 and T5 but higher (P<0.05) than that of T1. The weight of fat for T1 was similar (p>0.05) to that of T3 but lower than that of the other treatments.

The overall proportion of muscle and fat did not significantly differ (P>0.05) among treatments. However, the overall proportion of bone was significantly lower (P<0.01) in T1 than in T2, T3 and T4. According to Ameha (2008), the ideal carcass can be described as the one that has a minimum amount of bone, a maximum amount of muscle and an optimum amount of fat. Therefore, the highest proportion of muscle in T2 and bone in T1 suggested that supplementation enhanced carcass quality and among supplemented treatments supplementation of Gebisa (T2) induced production of more ideal carcass than other treatments.

Table 8. *Mean weight of muscle, bone and fat and their proportions of dissected half carcass of Arsi-Bale sheep fed a basal diet of fodder oat hay and supplemented with different varieties of vetch hay.*

Parameter		Treatments					SEM	SL
		T1	T2	T3	T4	T5		
Muscle	Kg	3.5^{c}	4.6^{a}	3.8^{bc}	3.9^{b}	4.1^{b}	0.08	***
	%	62.8	63.9	62.4	61.5	62.0	0.48	ns
Bone	Kg	1.2^{b}	1.3^{a}	1.2^{b}	1.2^{b}	1.3^{a}	0.02	*
	%	21.0^{a}	18.5^{c}	19.7^{bc}	18.7^{c}	20.1^{ab}	0.25	**
Fat	Kg	0.9^{b}	1.3^{a}	1.1^{ab}	1.3^{a}	1.2^{a}	0.04	*
	%	16.1	17.6	17.9	19.8	18.0	0.49	ns

^{a,b,c} means with different superscripts in a row are significantly different; *=(P<0.05); **=(P<0.01); ***=(P<0.001); ns = not significant; SL = Significance Level; SEM = Standard Error of Means; T1 = Fodder oat hay ad libitum; T2 = Fodder oat hay ad libitum + 350 g DM/day Gebisa; T3 = Fodder oat hay ad libitum + 350 g DM/day Lalisa; T4 = Fodder oat hay ad libitum + 350 g DM/day Abdeta; T5 = Fodder oat hay ad libitum + 350 g DM/day V. sativa.

In general, muscle comprised the highest proportion (61.5-63.9%) followed by bone (18.5-21.0%) and fat (16.1-19.8%). The weight of muscle (3.5-4.6 kg) and fat (0.9-1.3 kg) from the dissected half carcass in this study was much higher than the previous report in which 2.6-2-7 kg and 0.3-0.4 kg of muscle and fat, respectively, was reported from the dissected half carcass of the same breed of sheep fed Faba bean straw with concentrate mixture at a ratio of 70:30 [26]. Unlike muscle and fat, the weight of bone reported by the same author (1.1-1.2 kg) was comparable with the current result (1.2-1.3 kg). This shows that the experimental feeds used in the current study were able to produce the ideal carcass than earlier reports. Numerically, large amount of muscle was found on the leg followed by shoulder and neck parts of primal cuts, which was in line with the previous report [26]. Highest amount of fat was also deposited on leg followed by shoulder and neck in contrary to other author who reported highest accumulation of fat on breast and shank followed by rack [26].

The proportion of muscle in the current study (61.5-63.9%) was slightly higher than the value of 58.8-62.2 % reported by other author [26] and within the range of 51.09-76.77% lean meat of Arsi-Bale goats with different age group and feeding regime [28] and slightly lower than 63-67.4% lean meat for Borana and Arsi-Bale goats under different durations of feedlot management [29]. The proportion of bone in this study (18.5-21.0 %) was lower than earlier findings 25.7-30.9% [29], 25.11-35.89% [28] and 27.9-30.9% [26]. As per description of previous author, the ideal carcass is the one that has a minimum amount of bone, a maximum amount of muscle and an optimum amount of fat [1]. Similarly, other author [2] noted that the most common carcass quality assessment in small ruminants is particularly focusing on muscling or meatiness, hence muscling not body fat is the most important measure of sheep and goat carcass quality. The result of this study showed that the carcass produced from Arsi-Bale sheep fed fodder oat and vetch hay based diet is of maximum muscle, optimum fat and minimum bone. Therefore, it can be concluded that fodder oat and vetch hay based feeding is explicitly high potential feeding strategy not only in terms of producing high carcass yield, but also in terms of producing the ideal carcass as well.

4. Conclusions and Recommendations

From the results of this study, it was concluded that; There was a significant difference between vetch varieties in terms of carcass characteristics of sheep. Supplementation of Gebisa vetch variety (T2) induced highest carcass characteristics than all other treatments. Based on these findings Gebisa can be recommended as best performing variety for use as supplementary feed in sheep fattening. All dietary treatments in this study induced outstanding carcass characteristics of sheep, suggesting that fodder oat and vetch hay based feeding is explicitly high potential feeding strategy, particularly in smallholder production system where they can be cultivated easily. This paper considered only carcass yield and bone:muscle:fat ratio only as quality parameters. Therefore, further study should be conducted to evaluate the vetch varieties used in this study by considering detail carcass quality parameters.

Statements &Declarations

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Competing Interests

The authors declare no competing interests.

Author Contributions

All authors contributed to the study conception and design. Material preparation, data collection and analysis were performed by Berhanu Tassew. The first draft of the manuscript was written by Berhanu Tassew and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

Ethics Approval

The national guidelines for the care and use of animals have been followed.

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