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Effects of Replacing Parts of Concentrate with Thyme (*Thymus schimperi*) Leaf on Growth Performance, Carcass Characteristics and Sensory Quality of Meat of Arsi-Bale Sheep Fed on Barley Straw Basal Diet

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Abstract: Twenty-four intact male yearling Arsi-Bale sheep with an average body weight of 17.61±1.2 kg (Mean ± SD) were used to evaluate the effect of partial replacement of concentrate with thyme (*Thymus schimperi*) leaves on performance. The experiment consisted of ninety days growth experiment followed by a seven-day digestibility trial. Carcass traits and meat quality attributes were evaluated at the end of the digestibility trial. The experiment was arranged using a randomized complete block design. Dietary treatments comprised of 300 g concentrate mix (33% linseed cake and 67% wheat bran) (T1), 250 g concentrate mix + 50 g thyme leaf (T2), 225 g concentrate mix + 75 g/d thyme leaf (T3), and 200 g concentrate mix + 100 g thyme leaf (T4). Barley straw was offered *ad libitum* as a basal diet. The highest ($P<0.05$) total dry matter (DM) and organic matter (OM) intake were observed for T2, while the lowest was for T1 diets. The total crude protein (CP) intake decreased ($P<0.05$) with increasing levels of thyme leaf. The DM digestibility for T1 was greater ($P<0.05$) than that of T3 and T4 diets. The apparent digestibility of OM, CP and neutral detergent fiber was lower ($P<0.05$) for supplemented treatments compared with T1. The dressing percentage was greater ($P<0.05$) for sheep in T1, T2 and T3 compared with T4. Larger ($P<0.05$) rib-eye muscle area was observed for sheep in T1 and T2 diets than sheep in T3 and T4. Among the thyme leaf supplemented treatments, T3 and T4 had better ($P<0.05$) flavor than T2 while T4 had better $P<0.05$) aroma compared with T2. Mutton from the sheep fed on T1 diet had the highest ($P<0.01$) scores for tenderness. In conclusion, for most response variables, it is not important to include more than 50g thyme leaf but those who are interested in the aroma and flavor of mutton can feed 75 and 100 g thyme as part of concentrate mix for sheep fed barley straw-based diets.

Keywords: *Arsi-Bale sheep, Barley straw, Carcass traits, Digestibility, Meat quality, Thymus schmperi*

Introduction

Sheep production plays a vital role among all the livestock reared in Ethiopia. They are reared mainly as a source of income and as a source of meat for household consumption. Sheep are reared entirely under an extensive production system characterized by low input in form of feed and other allied factors associated with the production system. The productivity of sheep is very low as indicated by an annual off-take rate of 33% and an average carcass weight of 10 kg/head (CSA, 2010). The productivity is further influenced by the scarcity of feed in terms of quantity and quality, the genetic makeup of the animals and the periodic occurrence of diseases. However, according to Markos (2006), among the environmental factors, the major problem associated with poor animal (sheep) production in Ethiopia is an inadequate supply of both in quality and quantity of feed.

From the total supply of livestock feeds in Ethiopia, most of them are obtained from natural pasture, followed by crop residues, and a minuscule amount obtained from agro-industrial by-products (CSA, 2010). Cereal crop residues play a major role in the feeding of sheep under different production systems (Ajebu, 2010). However, these feedstuffs are characterized by a high content of indigestible fiber due to high lignin content. Fermentable energy and protein deficiencies in crop residues coupled with their low digestibility impair ruminal functions, intake and ruminant productivity (Sarwar *et al*., 2004).

Supplementing concentrates with poor-quality tropical forages is known to improve the feed intake and digestibility of roughages. However, the use of concentrates is limited especially under small-scale livestock production systems due to unreliable supply and high price to be used by the smallholder farmers. Consequently, the prospect for using cereal grains as livestock feed by smallholder farmers is quite limited (Ajebu, 2010). Therefore, it is important to find alternative sources of supplements, which could easily be obtained by farmers in their vicinity without incurring much additional cost. Among the different sources, the inclusion of the leaves of thyme (*Thymus schimperi*) to the regular diet of the sheep especially reared in areas where the plant is easily available is one of the most appropriate alternatives.

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Thyme is a type of medicinal herb grouped under the *Lamiaceae* family (Mikaili *et al*., 2010). Many species of the plant are classified under different genera of the family *Lamiaceae* and have been reported from different parts of the world. However, the two commonly available species endemic to Ethiopia are *Thymus schimperi* Ronniger and *T. serrulatus Hochst.ex* Benth (Asfaw *et al*., 2000). Thyme oil has been reported to be grouped under the top 10 of the essential oils accepted globally (Letchamo *et al*., 1995). The composition and amount of the essential oil is influenced by the season of harvesting (Atti-Santos *et al*., 2004) and also several non-genetic factors besides other agronomical reasons (Jordan *et al*., 2006). Thyme oil can be added to the diets of livestock to improve or alter rumen function as the naturally occurring compounds have a synergistic effect on the rumen microflora (Paulson, 2008). The herb can also help in stimulating appetite and digestion thereby helping in improving the performance of the animals (Afshar *et al*., 2012).

In the Bale zone, sheep are raised on natural pasture, fallow lands and crop residues, which are not quite sufficient to meet even the basic maintenance requirements. Thyme naturally grows in the areas and thus sheep are often seen to consume this plant alongside the conventional feed. It is traditionally said that the mutton from the locally reared Arsi-Bale sheep raised around the thyme growing area has some desirable flavor. As perceived by the residents of the area this unique and desirable flavor of the meat is believed to be associated with the consumption of thyme leaves by animals. Results from a study in northern Ethiopia indicated that feeding thyme leaves (100 g and 200 g) promoted feed intake, digestibility, growth performance and meat quality of the local sheep (Tewodros *et al*., 2013) compared with those fed hay alone and hay and 300g concentrate. However, the effects of supplementation of thyme leaves to the basal diet of wheat straw on the performance of sheep and its effect on the quality of the products obtained thereof too are not well studied. Therefore, this study was designed to assess the effects of partial replacement of concentrate mix with thyme *leaf* on intake, body weight gain, digestibility and carcass characteristics of Arsi-Bale sheep fed on barley straw basal diet.

Materials and Methods

Description of the Study Area and Preparation of Experimental Feeds

The study was conducted at Agarfa ATVET College, which is found in Oromia National Regional State in Bale zone in Agarfa district. The district is situated 458 km southeast of Addis Ababa. Agarfa ATVET College is located between $07^{0}017$'N Latitude and $39^{0}49$'E Longitude. The minimum and maximum annual temperature is 10 ^{o}C and 25 ^{o}C, respectively, with an average value of 7.5 ^{o}C. The average annual rainfall is 800 mm and bimodal, with the short rainy season reported between March until April and the long rainy season being from June to October (ABoFED, 2009).

The experimental feed consisted of a basal diet of barley (*Hordeum vulgare*) straw supplemented with linseed (*Linum usitatissimum*) cake and wheat (*T. aestivum*) bran as a partial replacement of thyme leaf. Linseed cake and wheat bran were purchased from the local market and Robe flour milling factory, respectively and stored under the shed to maintain its quality. Barely straw was obtained from Agarfa ATVET college farm. The collected straw was chopped using a machete to approximately 10cm to facilitate feeding. Straw was fed without any treatment. The thyme leaves were hand plucked at the flowering stage. Branches and twigs were carefully removed manually and the leaves were dried under shade. The dried leaves were crushed manually and stored in sacks until mixing with concentrates.

Animals and their Management

A total of twenty-six yearling Arsi-Bale (2 was a reserve in case of any death) rams with an average initial body weight of 17.61±1.2 kg (Mean ± SD) were purchased from the local market. The age of sheep was determined based on dentition. The animals were allowed a quarantine period of two weeks to the environment. During this period the animals were drenched with a broad spectrum of anti-helminthics (albendazole) against internal parasites and sprayed with acaricide (diazinon) against external parasites. Then, the experimental animals were placed in individual pens that were equipped with feeding troughs and watering buckets. Animals were adapted to the experimental feed for 14 days before the commencement of the trial. The experiment consisted of 90 days of feeding experiment followed by 7 days of digestibility trial.

Experimental Design and Treatments

A randomized complete block design was used for the experiment. At the end of the acclimatization period, the animals were grouped into six blocks of 4 animals each according to their initial body weights and the treatments were randomly assigned to each animal in a block. The concentrate mixture was comprised of wheat bran and linseed cake with the ratio of 2:1 (at a proportion of 67 % of wheat bran and 33 % linseed seed cake) on a DM basis, respectively. The supplement diets were offered in two equal portions twice a day at 08:00 h and 16:00 h. The basal diet (barley straw) was offered *ad libitum* at least at a 20% refusal level. The amount of wheat straw refusal was adjusted every three days to make sure that 20% is refusal is available. The daily total supplements were limited to 300g DM. Thyme leaf was incorporated with the amount of 33.3 %, 25% and 16.7 % of the total concentrate supplement for T4, T3 and T2, respectively (Table 1).

Feed Intake

The daily feed offered and refusal of each treatment diet was measured and recorded throughout the experimental period to assess the daily feed intake. Daily feed intake of the individual sheep was determined as a difference between the feed offered and refusal. Samples of feed offered were collected from each treatment diet and samples of the refusals were taken daily for each sheep over the experimental period. Then, the samples of refusal feed were pooled over the experimental period and sub-sampled for analysis.

Table 1. Experimental treatments

Treatments	Barley straw	Concentrate (g/DM/d)	Thyme leaf (g/DM/d)
T1	*Ad libitum*	300	-
T2	*Ad libitum*	250	50
T3	*Ad libitum*	225	75
T4	*Ad libitum*	200	100

Weight Change and Feed Conversion Efficiency

Averages of two consecutive live weights were taken after overnight fasting to determine the initial weight of the animals. Bodyweight (BW) measurements were taken every 14 days after overnight withdrawal of feed and water in the morning before the provision of the daily feed and water, and daily BW gain was determined as a difference between final and initial BW divided by the number of feeding days. The feed conversion efficiency (FCE) was calculated as a ratio of daily body weight gain to daily feed consumed.

Digestibility Trial

After the completion of ninety days of the feeding trial, a digestibility trial was initiated with the same animals and rations of the feeding trials. The digestibility experiment was conducted by keeping the animals in an individual pen permitting a separate collection of feces and equipped with feeders and water supplies. The animals were placed in their individual pen to which animals were adapted to the fecal bags for three days followed by 7 days of actual fecal collection. Feces voided were collected in the fecal bags over 24 hours period and weighed every morning for each sheep. Ten percent of the voided feces were sampled and pooled for each animal over the collection period of 7 days. The fecal samples were stored at a -20 ^{o}C deep freezer. After the seventh day, fecal samples were thawed at room temperature, thoroughly mixed and sub-sampled and partially dried in an oven at 60 ^{o}C for 72 h and ground in Wiley mill to pass 1 mm sieve screen and kept in airtight containers until chemical analysis.

Carcass Evaluation

At the end of the feeding and digestibility trial, three experimental animals from each treatment were withdrawn from the feed overnight. The Slaughter weight (SW) of each animal was taken 30 minutes before slaughter. The animals were killed by severing the jugular vein and carotid artery with a knife. The weight of the blood was estimated as a difference between the slaughter weight and weight after bleeding. The esophagus was tied to prevent the backflow of rumen content while suspending the animals for skinning. The skin was flayed carefully to avoid the adherence of fat and muscle tissue to the skin and was weighed. The empty body weight (EBW) was calculated as the difference between SW and gut content. Hot carcass weight (HCW) was determined by excluding contents of the thoracic, abdominal and pelvic cavities, head, skin, feet and tail of the animal. Dressing percentage (DP) was calculated based on the HCW divided by SW and/ HCW divided by EBW. The rib-eye muscle area of each animal was determined by cutting perpendicular to the backbone between the 11th and 12th ribs and tracing the left and right rib-eye muscles on butter paper (Galal *et al.,* 1979). The area was measured using a portable leaf area meter (model LI- 3000 A). The mean of the right and left cross-sectional areas were taken as a rib-eye muscle area measurement.

Mutton Quality Attributes

Meat samples of each treatment were collected after removing bone from the flesh, cut into pieces of an average of 40 g and labeled for identification. Then the meat samples were cooked in distilled water at 65^{o}C for 30 minutes (Fasae *et al.,* 2010). Cooking loss percentage was calculated as the difference between the weight of the meat sample before cooking and after cooking divided by the pre-cooked weights of the meat multiplied by 100 (Fasae *et al*., 2010). The myofibril fragment length of mutton was assessed under a digital microscope with 40x magnification (Gallo *et al*., 2009).

Sensory Analysis of Meat

The meat sample was taken from *the longissimus dorsi (L. dorsi*) muscle and a front leg for analysis of flavor, aroma, juiciness and tenderness. The analysis was made on cooked ram meat without salt or spices added. For the attributes, tenderness and juiciness, the foreleg was used whereas for all other sensory attributes the muscle *L. dorsi* (loin) was used. The meat was cooked over an electric oven at 165°C. The samples were immediately sliced into pieces of uniform dimensions (=50 g) labeled with 3-digit random numbers and randomly offered to the trained panel. The sensory quality of mutton was determined by developing a sensory questionnaire to measure the intensity based on a 9-point hedonic scale (like extremely as 9, dislike extremely as 1) for the flavor and aroma and a 5-point hedonic scale (very tender as 5, not tender as 1) for the tenderness and juiciness of cooked mutton meat (AMSA, 1978).

The test panelist consisted of eight persons chosen from the college community who are familiar with meat characteristics and consumption of mutton and were trained according to ISO 8586-1 (2012). There were training sessions using descriptors of flavor, aroma, tenderness and juiciness of cooked meat as reference. In the two first sessions, the tenderness, flavor, aroma and juiciness descriptors of raw and cooked lamb meat were studied; the next two sessions were concerned with identifying, selecting and quantifying attributes to evaluate the meat.

The panelists were given orientation and instructed to rinse their mouths with clean water before testing each sample to avoid sensory bias. The panelists were asked to rate the meat samples based on their degree of likeness (acceptance of the meat samples) for each sensory attribute by giving scores ranging from 1- 9 for flavor and aroma and 1-5 for tenderness. Each panelist evaluated each meat sample from the different treatments for the described sensory attributes. Rating of meat samples for flavor, and aroma were done by giving numerical values as follows: like extremely (9), like very much (8), like moderately (7), like slightly (6), neither like nor dislike (5), dislike slightly (4), dislike moderately (3), dislike very much (2) and dislike extremely (1). Rating of tenderness and juiciness were done by giving numerical values as follows: very tender/juicy (5), moderately tender/juicy (4), just tender/juicy (3), less tender/juicy (2), not tender/juicy (1) (AMSA, 1978).

Chemical Analysis

The samples (feed offer, refusal and feces) were partially dried in a forced draft oven at 60°C for 48 hours. The dried samples were grounded to pass through 1mm Wiley mill sieve size. The chemical analysis was run in triplicates. Finally, dry matter (DM), ash and crude protein (CP) were determined according to the procedure of A.O.A.C. (1990). The neutral detergent fiber (NDF), acid detergent fiber (ADF) and acid detergent lignin (ADL) were determined using the detergent extraction method developed by Van Soest and Robertson (1985) with an ANKOM® 200 fiber Analyzer (ANKOM Technology Corp., Fairport, NY, USA).

Statistical Analysis

Data generated on feed intake, digestibility, weight gain and carcass parameters were analyzed using the General Linear Model (GLM) procedure of the SAS (SAS, 2002). When F-test declared significance at $p<0.05$, treatment means were separated using Duncan's multiple range test. The statistical model used for the analysis was:

$Y_{ijk} = \mu + t_i + b_j + e_{ijk}$, where Y = response variable; μ = the overall mean; t_i = i^{th} treatment effect; b_j = j^{th} block effect; e_{ij}= the random error.

The sensory score data was analyzed by the analysis of variance technique for CRD using the general linear model procedure of SAS (2002). Means separation was done using the least significant difference test when ANOVA showed the presence of a significant difference between treatment means. The model used for the analysis of sensory score data was $Y_{ij} = \mu + \alpha_i + e_{ij}$ where Y_{ij} = response variable; μ = the overall mean; α_i = the treatment effect; e_{ij}= the random error.

Results

Chemical Composition of Treatment Feeds

The CP content of thyme was low compared with that of wheat bran (Table 2). Linseed cake had a high content of CP followed by wheat bran and thyme leaf meal. The fiber contents (NDF and ADF) were high in both linseed cake and wheat bran compared to thyme leaf meal. Among the supplement ingredients, wheat bran contained high NDF and ADF.

Table 2. Chemical composition (% DM unless specified) of feed ingredients

Ingredients	Chemical composition				
	DM %	Ash	CP	NDF	ADF
Barley straw	94.4	10.1	4.8	77.1	50.1
Linseed cake	97.4	8.0	46.8	44.0	11.7
Wheat bran	95.6	3.6	18.5	47.4	12.6
Thyme leaf	96.0	5.0	14.0	41.1	10.2

DM= Dry matter; CP= Crude protein; ADF= Acid detergent fiber; NDF= Neutral detergent fiber; T1= Straw ad libitum + 300 g concentrate; T2= Straw ad libitum + 250 g concentrate + 50 g thyme leaf; T3= Straw ad libitum + 225 g concentrate + 75 g thyme leaf; T4= Straw ad libitum +200 g concentrate +100 g thyme leaf.

Dry Matter and Nutrient Intake

The DM and nutrient intakes of Arsi-Bale sheep during the feeding trial are summarized in Table 3. Barley straw DM intake was lower ($P<0.05$) for T1 than the supplemented groups. On the other hand, there was a declining trend in barley straw DM intake with increasing levels of thyme among the supplemented group ($P<0.001$). Concentrate mix, as well as the supplemental thyme leaves, were readily consumed by all animals with no leftovers.

The highest ($P<0.05$) total DM and OM intake of rams were observed for T2, while the lowest ($P<0.05$) was for T1 diets. Total DM and OM intake decreased with an increased amount of thyme across the treatments. The total crude protein intake decreased ($P<0.05$) with increasing levels of thyme leaf.

Body Weight Change and Feed Conversion Efficiency

The mean initial body weights (BW), final BW, average daily body weight gain (ADG) and feed conversion efficiency (FCE) are presented in Table 4. The ADG for T1 was greater ($P<0.05$) than T3 and T4, whereas T2 had an intermediate value. The highest ($P<0.05$) FCE was obtained for T1, while the lowest ($P<0.05$) was for T3 and T4.

Dry Matter and Nutrient Digestibility

The apparent digestibility coefficients of DM and nutrients for Arsi-Bale sheep fed barley straw as a basal diet supplemented with thyme leaf at different levels are presented in Table 5. The DM digestibility for T1 was greater than those fed T3 and T4 diets. Similarly, the NDF and ADF digestibility for T1 was greater (P<0.05) than T3 and T4. The apparent digestibility of OM, CP and NDF was lower (P<0.05) for supplemented treatments compared with T1.

Table 3. Daily dry matter and nutrient intakes of Arsi-Bale sheep fed barley straw supplemented with different levels of thyme (*Thymus schimperi*)

Intake	Treatments					
	T1	T2	T3	T4	SEM	p-value
Dry matter intake (g/d)						
Straw	377.5^{d}	475.5^{a}	445.5^{b}	436.5^{c}	50.8	0.0001
Supplement	288.6^{a}	288.6^{a}	288.3^{b}	287.4^{c}	2.71	0.0001
Total dry matter	666.1^{d}	764.1^{a}	733.8^{b}	723.9^{c}	50.8	0.0001
Organic matter	635.4^{d}	719.6^{a}	693.4^{b}	684.6^{c}	43.3	0.0002
Crude protein	101.4^{a}	99.2^{b}	94.3^{c}	89.0^{d}	2.21	0.0001
Neutral detergent fiber	399.2^{c}	474.3^{a}	445.1^{b}	440.9^{b}	42.2	0.0001
Acid detergent fiber	434.7^{a}	283.2^{b}	260.4^{c}	254.5^{d}	31.0	0.0022
Estimated ME (MJ/head/d)	8.25^{b}	8.10^{b}	8.74^{a}	8.02^{b}	4.52	0.0002

[a-d] means with different lowercase letters in the same row differ significantly (p<0.05); SEM= Standard error of mean; ME (MJ/Kg)= 0.016 X DOMD; ADF= Acid detergent fiber; NDF= Neutral detergent fiber; ME= Metabolizable energy; T1= Straw ad libitum + 300 g concentrate; T2= Straw ad libitum + 250 g concentrate + 50 g thyme leaf; T3= Straw ad libitum + 225g concentrate + 75g thyme leaf; T4= Straw ad libitum +200 g concentrate +100 g thyme leaf.

Table 4. Bodyweight gain of Arsi-Bale sheep fed barley straw supplemented with different levels of thyme (*Thymus schimperi*)

Parameter	Treatments					
	T1	T2	T3	T4	SEM	p-value
Final body weight (kg)	24.33	24.17	23.33	23.20	1.46	0.4680
Total weight change (kg)	6.83^{a}	6.50^{ab}	5.67^{b}	5.6^{b}	0.82	0.0481
Average daily gain (g)	75.93^{a}	72.22^{ab}	62.96^{b}	62.22^{b}	9.14	0.0481
FCE (g BWG/ g DMI)	0.114^{a}	0.095^{b}	0.086^{c}	0.087^{c}	0.01	0.0001

[a-c] means with different lowercase letters in the same row differ significantly (p<0.05); SEM= Standard error of mean; FCE= Feed conversion efficiency; BWG= Body weight gain; DMI= Dry matter intake; T1= Straw ad libitum + 300g concentrate; T2= Straw ad libitum + 250g concentrate + 50 g thyme leaf; T3= Straw ad libitum + 225g concentrate + 75g thyme leaf; T4= Straw ad libitum +200g concentrate +100g thyme leaf.

Table 5. Dry matter and nutrient digestibility coefficient of Arsi- Bale sheep fed barley straw supplemented with different levels of thyme (*Thymus schimperi*)

Digestibility coefficients	Treatments					
	T1	T2	T3	T4	SEM	p-value
Dry matter	0.65^{a}	0.63^{ab}	0.61^{bc}	0.60^{c}	0.05	0.0001
Organic matter	0.72^{a}	0.70^{b}	0.69^{b}	0.69^{b}	0.04	0.0002
Crude protein	0.89^{a}	0.87^{b}	0.82^{d}	0.83^{c}	0.02	0.0001
Neutral detergent fiber	0.66^{a}	0.62^{b}	0.59^{c}	0.59^{c}	0.04	0.0001
Acid neutral detergent	0.63^{a}	0.60^{ab}	0.59^{b}	0.57^{b}	0.08	0.0022

[a-c] means with different lowercase letters in the same row differ significantly (p<0.05); SEM= Standard error of mean; T1= Straw ad libitum + 300 g concentrate; T2= Straw ad libitum + 250 g concentrate + 50 g thyme leaf; T3= Straw ad libitum + 225 g concentrate + 75g thyme leaf; T4= Straw ad libitum +200 g concentrate +100 g thyme leaf.

Carcass Characteristics

The mean values for the pre-slaughter weight (SLW), empty body weight (EBW), hot carcass weight (HCW), dressing percentage (DP) and rib-eye area (REYA) of the experimental sheep are given in Table 6. The SLW and EBW were similar (P>0.05) among treatments. The HCW and DP on SLW and EBW bases were higher (P<0.05) for T1, T2 and T3 compared with T4, but the values for T1, T2 and T3 were similar (P<0.05) among each other. Larger (P<0.05) REYA was observed for the rams reared on T1 and T2 diets.

Mutton Quality and Sensory Attributes

The cooking loss, cooking yield, fiber fragment length and sensory attributes of meat of sheep supplemented with different levels of dried thyme leaf are presented in Table 7. The values of aroma and flavor intensity scores were higher (P<0.0001) for thyme leaf supplemented treatments than T1 diet. However, among the thyme leaf supplemented treatments, T3 and T4 had better ($P<0.05$) flavors than T2 while T4 had better $P<0.05$) aroma compared with T2.

Mutton tenderness intensity scores decreased ($P<0.05$) with the increasing levels of thyme leaf in the diets. Among the treatments, the values of tenderness intensity score was highest ($P<0.05$) for T1, while the lowest ($P<0.05$) was for T4. The highest ($P<0.05$) values of juiciness intensity score were observed for T1 and T2, while the lowest ($P<0.05$) was for T4.

There was no significant difference ($P>0.05$) in cooking loss and cooking yield of sheep meat among the treatments. However, the length of the myofibril fragment of mutton was higher for T2 and T3 compared with T4.

Table 6. Main carcass characteristics of Arsi-Bale sheep fed barley straw basal diet supplemented with different levels of thyme (*Thymus schimperi*)

Parameters	Treatments					
	T1	T2	T3	T4	SEM	p-value
Slaughter body weight (kg)	23.33	24.00	22.67	22.33	1.12	0.3363
Empty body weight (kg)	17.03	17.40	16.76	17.80	0.44	0.2310
Hot carcass weight (kg)	9.72^a	9.85^a	9.48^a	7.92^b	1.63	0.0022
Dressing percentage						
Slaughter weight Basis (%)	41.76^a	41.06^a	41.80^a	35.47^b	0.50	0.0037
Empty weight Basis (%)	57.07^a	56.61^a	56.50^a	53.52^b	1.34	0.0415
Rib eye area (cm^2)	10.74^a	10.78^a	9.73^b	8.23^c	0.002	0.0056

$^{a-c}$ *means with different lowercase letters in the same row differ significantly (p<0.05); SEM= Standard error of mean; T1= Straw ad libitum + 300 g concentrate; T2= Straw ad libitum + 250 g concentrate + 50 g thyme leaf; T3= Straw ad libitum + 225 g concentrate + 75 g thyme leaf; T4= Straw ad libitum +200 g concentrate +100 g thyme leaf.*

Table 7. The effect of Thyme supplementation on mutton quality sensory attributes of meat of Arsi-Bale sheep

Parameters	Treatments				SEM	p-value
	T1	T2	T3	T4		
Aroma	6.1^c	7.3^b	7.8^{ab}	8.1^a	0.77	0.0001
Flavor	5.9^c	7.0^b	8.0^a	8.3^a	0.77	0.0001
Tenderness	4.3^a	3.5^b	3.3^{bc}	2.6^c	0.68	0.0006
Juiciness	4.3^a	4.3^a	3.4^b	2.5^c	0.78	0.0002
Cooking loss (%)	20.73	15.28	25.26	28.42	16.3	0.7765
Cooking yield (%)	79.27	84.72	74.74	71.58	16.3	0.7765
Myofibril diameter	0.770^{ab}	0.944^a	0.833^a	0.543^b	0.12	0.0231

$^{a-c}$*means with different lowercase letters in the same row differ significantly (p<0.05); SEM= Standard error of mean; T1= Straw ad libitum + 300g concentrate; T2= Straw ad libitum + 250g concentrate + 50 g thyme leaf; T3= Straw ad libitum + 225g concentrate + 75g thyme leaf; T4= Straw ad libitum +200g concentrate +100g thyme leaf.*

Discussion

Chemical Composition of Experimental Feeds

The CP content of barley straw in the current experiment was not quite sufficient to support the optimum activity of micro-organisms in the rumen as has been noted by Van Soest (1994). Therefore, to meet the basic maintenance requirements concentrate supplementation is required (Mc Donald *et al*., 2002). Similarly, Hadjipanyiotou and Morand-Fehr (1991) reported that feeding energy concentrates with barley straw cover the maintenance requirement of Awassi sheep.

The observed CP content of barley straw in the current study was lower than the value (5.4 % CP) reported by FAO (1977). However, the CP content of barley straw in the present study was higher than the result (4.4%) of Seyoum and Zinash (1989). However, the CP content of barley straw in the current study was comparable with the findings (4.66%) of Neamn *et al.* (2014). The differences as observed can be attributed to the varietal differences as stated by Mc Donald *et al.* (2002).

According to Lonsdale (1989), the CP content of wheat bran varies from 13.3 to 17.0 %. The result of the current study was comparable at the higher end of the above-mentioned ranges, which may be due to the method of processing and also to the varietal differences as noted by Haska *et al.* (2008). Moreover, the CP content of wheat bran used in this experiment was comparable with the results (17.5 % and 16.9 %) of Neamn *et al.* (2014) and Mulugeta and Gebrehiwot (2013), respectively.

The study showed that the results of CP contents of thyme in the current experiment were higher compared with the result (7.2 %) of Tewodros *et al.* (2013) for *Thymus serrulatus* and the result (9 %) of Ali (2014) for *Thymus Vulgaries*. The differences in the two studies might be due to differences in the season and method of harvesting and drying the supplements.

Dry Matter and Nutrient Intake

The higher DM intake of barley straw for sheep receiving thyme supplemented ration (T2, T3, and T4) might be attributed to the lower nutrient content of thyme compared with concentrate feed. This may be attributed to a natural habit of increasing the intake of feed to meet the basic nutrient requirements, the observation was in accordance with those of Firisa *et al.* (2013) who reported that the DM intake was higher (in comparison to the non-supplemented group) in Horro lambs supplemented with *Vernonia amygdalina* leaves. Similarly, Neamn *et al.* (2014) noted that basal DM intake was highest in diets without any supplementation when compared to the sheep receiving *Acacia alibidae* and *Acacia seyal* leaves as supplements. Contrary to the current study, Takele and Getachew (2011) indicated that there was no significant difference in DM intake of hay between supplemented and non-supplemented groups of sheep, which may be attributed to the type of feed offered and the quality of the hay used as a basal diet.

Consistent with the current experiment, Tewodros *et al.* (2013) reported that the total DM and OM intake of sheep that received the thyme supplements were higher than those of the non-supplemented group which is The higher DM and OM intake of sheep reared on T2 diet could be associated with the synergistic effect of feeding the thyme leaf supplements with that of the basal diet and concentrate, the observations are in close accordance with those of Khamisabadi *et al.* (2015) who concluded that addition of thyme and peppermint at a concentration of 3% of forage per diet increased the feed intake of lambs, while at a higher dosage the palatability of the supplementary feed may have decreased which adversely influence the intake of the feed as a whole. Similar observations were also reported by Laitat *et al.* (2004) who reported decreased intake of feed with increased inclusion of thyme leaves in the diet, due to a relatively higher content of thymol which may give an unpleasant taste and flavor to the feed thereby desisting the sheep from consumption of the feed.

In the current study, the decrease in CP intake with the increase in thyme level in the ration might be due to the lower CP content of the thyme leaves compared to those of the concentrate which is consistent with the findings of Tewodros *et al.* (2013) who reported that the CP intake was higher in Menz sheep supplemented with concentrate mix when compared to those receiving a different proportion of thyme leaf. Consistently, Manh *et al.* (2012) observed that as the levels of eucalyptus leaf meal supplementation increased across the treatments, the CP intake decreased.

Body Weight Change and Feed Conversion Efficiency

Performance of animals is the effects of several synergistic factors and also depend on the type of feed it receives and also on the combination and concentration of the different nutrients that influence the overall intake, digestibility, and metabolic efficiency of absorbed nutrients (Minson, 1990). The higher average daily gain and feed conversion efficiency for T1 might be due to the higher CP intake compared with thyme supplemented groups. The current finding is similar to the result of Tewodros *et al.* (2013) who reported that the ADG of Menz sheep receiving 300g/d concentrate was higher than the sheep receiving *adlibitum* hay alone, 200 g/d concentrate + 100 g/d thyme and 100 g/d concentrate + 200 g/d thyme. Contrary to the present finding, Feleke *et al.* (2011) indicated that the total ADG of sheep receiving control diet were lower than sheep fed graded levels of moringa (*Moringa stenopetala*) leaf meal. The ADG results of the current study were comparable with the results (60.60 - 63.67 g) of Bahran (2014) for Horro yearling lambs supplemented with 60 % cassava leaf meal and 40 % concentrate mix at 300 g DM/d. However, the ADG in the current study was higher than the results (29.6 - 46. 4 g) of Dereje (2014) for sheep fed tagasaste (*Chamaecytisus palmensis)* forage.

Dry Matter and Nutrient Digestibility

In the current study, the lower apparent DM digestibility coefficient for T4 could be due to the lower CP content of the ration and the presence of thyme leaf at a higher level in the ration. This could be due to the existence of thyme oil which might have antagonistic properties on the rumen microflora. The observations were consistent with those of Evans and Martin (2000) who noted that thymol influences the energy metabolism of rumen bacteria which can reduce the overall nutrient digestion and also total volatile fatty acid production when added at higher doses. Alsaht *et al.* (2014) indicated that digestibility of fiber decreased by 35 % at a higher dose (1,600 mg/d) of thymol added to the diet of growing lamb fed concentrates vis-a-vis those of lambs raised on a non-supplemented diet. The findings from the current study are also similar to the work of Tewodros et *al.* (2013) who reported lower DM digestibility in lambs reared on 100 g thyme and 200 g concentrate ration when compared to the lambs fed in 200 g thyme and 100 g of concentrate ration.

The DM digestibility for the feeds used in the present study decreased linearly with increasing levels of thyme leaves which is in accordance with the findings of Manh *et al.* (2012) for cattle fed with eucalyptus leaf meal with rice straw as basal diet. However, the results of DM digestibility in the current study was higher than the results (57.3- 58.3 %) of Bahran (2014) for sheep fed cassava leaf meal and significantly higher than the results (46.0 - 60.0 %) of Berhanu *et al.* (2014) for Washera sheep supplemented with *Millettia ferruginea* leaf meal fed on natural pasture grass hay, while it was lower than the results (68.58 - 77.75 %) of Sultana *et al.* (2015) for goat fed different levels of Moringa foliage (*Moringa oleifera*). The variation of apparent DM digestibility among different experiments might be associated with the presence of a limiting factor that hinders DM digestibility as noted by Berhanu *et al.* (2014) and also the difference in the nutritional characteristics of different supplements.

The higher apparent CP and NDF digestibility for T1 compared with the group in the current study might be the higher CP content of the diet. Unlike the present finding, Gerencser *et al.* (2014) observed no significant differences in the digestibility of ADF and NDF by substitution of 3% thyme leaves for rabbits fed on alfalfa meal, which might be attributed to the species difference of thyme used in the preparation of the leaf meal. The study by Manh *et al.* (2012) too indicated that supplementation of *Eucalyptus camaldulensis* leaf meal had no significant effect on the apparent digestibility of NDF and ADF among dairy cattle fed on rice straw as a basal diet. The differences as observed may be due to the effect of thymol which depresses the intake of feed because of it being less palatable and also that it may disrupt the normal rumen microflora thereby depressing growth.

Carcass Characteristics

In the current study, the higher carcass weight observed for T1, T2 and T3 diets may be due to the higher carcass and the lower empty body weight obtained for each corresponding treatment. Similar observations were reported by Berhanu *et al.* (2014) who indicated that a high dressing percentage was observed for those sheep fed on 450 g/d of concentrates when compared to sheep raised on a similar amount of *Millettia ferruginea* (Birbira) supplementation. However, the results were not similar to those of Bahran (2014) who observed that there were no significant differences among the treatment groups when the sheep were reared on cassava supplemented diet.

In the present study, the decrease in hot carcass weight and dressing percentage with increasing thyme levels in the ration could be associated with the lower CP content of thyme that affects the body weight gain of animals. The observations are in agreement with those of Papi *et al.* (2011) who reported improvement in dressing percentage with increasing levels of concentrate in the diet of different animal species. The improvement in dressing percentage may be attributed to better muscular development among the sheep reared on a high protein diet. The observations are in line with those of Pittroff *et al.* (2006) who noted that weight change and organ mass of finishing lambs improved when they are fed on a high protein diet. Tewodros *et al.* (2013) observed that hot carcass weight and dressing percentage were higher for sheep receiving lower dosages of thyme (100 g thyme + 200 g concentrate) diet when compared with sheep fed on a diet containing 200 g thyme + 100 g concentrate.

The higher dressing percentage observed for sheep receiving T1, T2, and T3 diets compared to those reared on T4 diet might be due to the higher carcass weight which may be associated with the higher nutrient digestibility. This might have resulted in higher ADG and HCW in sheep receiving T1, T2 and T3 diets as compared to those reared on T4 diet. McDonald *et al.* (2002) stated that nutrition, age, sex, genetics, season and other related factors affect the growth and carcass traits of animals. The mean dressing percentage on slaughter weight and empty body weight bases observed in the current study is comparable with the result (33.3 - 42.0%) of Tewodros *et al.* (2013) in sheep fed different levels of thyme leaf. The dressing percentage in the current experiment is higher than the result (31.7 - 33.9%) of Berhanu et *al.* (2014) for sheep fed in *Millettia ferruginea* foliage supplementation but lower than the result (44.21- 44.76 %) of Bahran (2014) for sheep fed in cassava leaf supplementation. The lower dressing percentages as observed may be attributed to the lower slaughter weight of sheep which is in agreement with those of Preston and Willis (1974) who stated that dressing percentage increased with live weight increase till a point at which it tended to cease.

Rib-eye muscle area (REMA) is related to the development of muscle *(L dorsii*) in the carcass and higher lean/bone ratio (Wolf *et al.*, 1980). The larger REMA as observed for sheep raised on T1 and T2 diets of the current study might be attributed to the better muscular development of animals as a result of good CP content of ration compared with other thyme leaf supplemented ration. Yilkal *et al.* (2014) observed that a lower value of REMA was obtained in non-supplemented sheep probably be due to the lower CP and higher NDF value of the hay. The observed REMA in the current study was higher than the results (4.9-10.7 cm^2) of Tewodros *et al.* (2013) when Menz sheep were fed a basal diet of hay supplemented with dried thyme leaf but lower than the results (10.57-10.89 cm^2) of Bahran (2014) in Horro sheep supplemented with cassava leaves.

Mutton Quality and Sensory Attributes

In the current study, the non-significant differences in cooking loss and cooking yield of mutton across all dietary treatments could be due to the relatively similar water-holding capacity of mutton. The observations agreed with those of Osório *et al.* (2009) who stated that the amount of juices that is released from cooked meat depends on water holding capacity, pre-concentration of collagen at 65-70°C and denaturation of protein. Aaslyng *et al.* (2003) noted that water is probably lost due to the denaturation of heat-sensitive proteins during the cooking of meat, which causes less water to be trapped within the protein structures held by capillary force. In agreement with the present finding, Abd El-aal and Suliman (2008) reported a lack of difference in cooking loss and cooking yield of mutton for sheep supplemented with different levels of *Leucaena* hay and Bello and Tsado (2014) for sheep supplemented with varying levels of dried poultry dropping.

The greater length of myofibril fragments of mutton for sheep receiving T2 and T3 diets might be due to the greater myofibril sizes of muscle obtained from those lambs. This indicates mutton from sheep raised on T2 and T3 diets was less tender than those reared on T1 diets. This might be because meat tenderness is inversely related to muscle myofibril length (Hopkins *et al*., 2005). In line with the current finding, Gallo *et al.* (2009) reported that myofibril length of lambs was greater for those fed in concentrate diet than pasture supplemented diet.

The pleasant aroma and intensified flavor of mutton obtained from those reared on a supplementary diet may be attributed to the deposition of aromatic constituents of thymol in the muscles. The current result is in agreement with the findings of Tewodros *et al.* (2013) who reported enhanced intensity of aroma and flavor with an increase in the levels of supplementation of thyme. In line with the current study, Naser (2007) reported that most of the plants having aromatic and medicinal properties imbibe their flavor in the meat and also within intramuscular fat. A study by Young *et al.* (1997) also indicated the intensity of flavors in mutton may be attributed to the smell of volatile compounds that are found in fat. The levels of tenderness and juiciness were low in the thyme supplemented group and lowest in lambs that received the highest supplementation. This may be attributed to higher fat deposition inside the muscle (marbling) resulting from the higher nutrient concentration of concentrate compared with supplemental leaf meal (Turner *et al*., 2003). In this regard, Ameha (2006) stated that the deposition of fat among the muscle fibers (marbling) as the animal grows and matures on a high-energy ration can improve tenderness. Similarly, Priolo *et al.* (2002) pointed out that meat tenderness could be affected either through the direct effect of the fat, which is softer than lean and/or by an indirect effect of reduced muscle fiber length. Contrary to the present findings, Arsenos *et al.* (2002) reported a lack of significant difference in tenderness score values of mutton between lambs reared based on pasture and concentrate diets**.** Moreover, findings of a study by Bello and Tsado (2014) indicated that significant differences were not observed in meat tenderness scores between the sheep fed on sorghum stover and those supplemented with dried poultry dropping.

The higher Juiciness scores in the mutton of sheep consumed T1 and T2 diets compared to those receiving T3 and T4 could be associated with a relatively higher firmness and intramuscular fat deposition (marbling) of mutton resulting from a higher concentration of nutrients among those treatment diets. The observations are similar to those of Carpenter *et al.* (1968) who noted that firmness in meat is associated with a rigid structure, high juice retention, and limited losses of fluid during processing or cooking. However, the presence of intramuscular fat deposits can increase apparent firmness without actually influencing fluid retention. Similarly, Hocquette *et al.* (2010) also stated that that intramuscular fat positively influences flavor, juiciness, tenderness and/or firmness and the overall acceptability of meat.

Conclusion

In conclusion for most response variables, it is not important to include more than 50g thyme leaf but those who are interested in the aroma and flavor of mutton can feed 75 and 100g thyme as part of concentrate mix for sheep fed barley straw-based diets.

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Conflict of Interests

The authors declare that they have no competing interests.

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