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Original Research

Carcass Yield and Composition of Supplementing Hararghe Highland Sheep with *Ficus sur* (cv. Forssk.) Fruits to a Basal Diet of Natural Pasture Hay

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Abstract

The experiment was conducted to evaluate the supplementary value of dried and ground *Ficus sur* fruits (FSF) mixed at different proportions with oats grain (OG) on carcass yield, carcass composition, and pH concentration. Thirty Hararghe highland lambs with initial live weights of 14.32±0.25kg (mean±SEM) were used for the experiment. The experimental sheep were grouped into 5 based on their initial body weight. Thus, the experiment was laid out in a randomized complete block design (RCBD) consisting of 5 treatments and 6 replications. The treatments were: ad libitum natural pasture hay (control); 100%FSF:0%OG [100FSF]; 67%FSF:33%OG [67FSF]; 33%FSF:67%OG [33FSF]; 0%FSF:100%OG [0FSF], which were randomly assigned to the sheep in each block. Noug seed (*Gizotia abysinica*) cake (NSC) was supplemented at isonitrogenous levels to all treatments and control diets. No significant (P>0.05) effect of the dietary treatments was observed on carcass parameters and most of the edible and non-edible offal components. The carcass of lambs fed 100FSF diet consist the highest (P<0.001) moisture and crude protein (CP), but the least ether extract (EE) as compared to those consumed 0FSF diet. The pH of the carcass consistently declined from the initial measure taken at 45 minutes post-evisceration to measurement taken at 24 hours. Carcass of lamb fed treatment diets 67FSF and 100FSF have better maintained pH value within the desirable range. Hence, it can be concluded that feeding FSF to Hararghe highland sheep as a supplement to natural pasture hay based diet with sufficient protein supplement improved carcass yield and pH as compared to oat grains.

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INTRODUCTION

Livestock sector is the backbone of agriculture in Ethiopia whereby most domestic animals serve as sources of food, income, and supporting crop productions in different ways. Among livestock resources, sheep is the second populous to cattle with an estimate number of about 26 million (IGAD, 2009). Sheep production is widely practiced in Ethiopia due to many important attributes such as quantitatively low feed requirement and low initial cost of production (Adane, 2008); ease of handling; docile temperament; fast return; adaptation to diverse climates and production systems as compared to large ruminants (Khan *et al*., 2003). Among many other products of sheep, mutton is the main product utilized by all Ethiopian communities (Addass *et al*., 2010), with no discrimination by all religious groups, age, and gender. However, despite the potential, meat production from sheep in the country remained low.

Among the major constraints that limit sheep production, in general, feed shortage is on the top of the list of factors (Adane and Girma, 2008). According to Alemu (2008), about two-third of livestock production in Ethiopia is affected by nutrition. Research reports (Adugna, 2007; Yoseph *et al*., 2002) have shown that natural pasture and crop residues are the major sources of animal feeds in Ethiopia. However, these feed resources are poor in energy and crude protein contents and their quantity is not sufficient to support livestock, particularly during the dry season where there is critical feed shortage. Supply of conventional supplements such as agro-industrial by-products is limited and its price remains escalating, which hinders its use as supplement by smallholder farmers. Although grains such as oats grains can be used as energy supplement, it becomes staple diet for human being in most part of the country and not economical to use as animal feed. It is, therefore, imperative to search for alternative non-conventional feeds.

Ficus sur fruits (FSF) is naturally available feed resource in many parts of the tropics. It contains high amount of soluble carbon and could be used as energy supplement to poor quality natural feeds such as natural pasture and crop residues. *Ficus sur* is widely distributed in most part of Ethiopia and are freely accessed by smallholder farmers. In the country, FSF has been used locally as feed for centuries by different classes of livestock. During the dry season, the fruits are ripen and fall on the ground and are easily accessed and consumed by animals. Thus, it serves as an important supplement to animal grazing on poor pasture and crop aftermath. Moreover, *Ficus sur* trees serve as natural shade and resting area to livestock, which can be considered as an important role of the tree since the high environmental temperature is one of the stressors to the extensive system of animal production, particularly under the scenario of the current global temperature rise.

Despite its importance, the effect of this fruit on product yield and quality of replacing the fruit with other energy supplement has not been studied. Therefore, this study was aimed at evaluating the effects of feeding FSF on carcass yield, composition and pH concentration of Hararghe highland sheep as compared to feeding oats grain.

MATERIALS AND METHODS

Study Site

The study was conducted at Haramaya University sheep farm, located at 9^{o} 26'N latitude and 42^{o}3'E longitude in eastern Ethiopia. The altitude of the area is about 1980 meters above sea level and the mean annual rainfall is about 910 mm with a range of 560-1260 mm. The mean maximum and minimum temperatures are 23.4 and 8.25 ^{0}C, respectively (summary report from Haramaya University Meteorological Station, 2012).

Animals and Management

A total of 30 yearling intact male Hararghe highland sheep with similar body condition were purchased from Kulubi open market. The animals were transported to Haramaya University and quarantined for 3-weeks during which they were sprayed with accaricides against external parasites; treated with *ivermectin* injection against internal parasites and *Penistrep* against Pneumonia disease. During this period, animals were fed with natural pasture hay with noug seed cake supplement. At the end of the quarantine period, healthy animals with uniform condition were selected for the study and provided with ear-tag. The animals were randomly assigned to individual pens furnished with feeder and waterer in the experiment house.

Treatments and Experimental Design

The different dietary treatments used in the experiments are natural pasture hay offered *ad libitum* (control); natural pasture hay *ad libitum* and supplemented with either of the four diets, namely 100% *Ficus sur* fruits (FSF) and 0% oat grain(OG) [100FSF], 67%FSF and 33%OG [67FSF]; 33%FSF and 67%OG [33FSF]; or 0%FSF and 100%OG [0FSF]. Noug seed cake (NSC) was included in the diet across all the treatments to meet the protein requirement for maintenance at isonitrogenous level. The experiment was laid out in a randomized complete block design (RCBD) with five treatments. The animals were grouped into six blocks based on their initial body weight and dietary treatments were randomly distributed to the animals within each block.

Table 1: Treatments and chemical composition of feed stuff on DM basis

Ingredients (g)	Treatments				
	Control	100FSF	67FSF	33FSF	0FSF
Ficus sur fruits	0	300	201	99	0
Oats grain	0	0	99	201	300
Noug seed cake	225	210	190	170	150
Chemical composition (%)					
Dry matter	91.8	91.4	91.4	91.4	91.4
Ash	9.3	8.1	7.3	6.9	5.6
Crude protein	15.4	15.4	15.4	15.4	15.4
Neutral detergent fiber	58.3	33.7	35.2	36.8	38.6
Acid detergent fiber	41.1	22.6	23.1	23.7	24.3
Hemicelluloses	17.1	11.1	12.0	13.1	14.3
Cellulose	33.6	17.2	17.7	18.3	18.8
Acid detergent lignin	7.6	5.4	5.4	5.5	5.5
ME calculated (MJ/kg DM)	8.6	10.4	10.2	9.9	9.6

FSF= *Ficus sur* fruits; ME= metabolizable energy; DM= dry matter*Natural pasture hay was offered *ad libitum* whereas noug seed cake was given to make the diets of all animals isonitrogenous; 100FSF = 100% FSF with 0% oats grain; 67FSF= 67% FSF with 33% oats grain; 33FSF= 33% FSF with 67% oats grain; 0FSF= 0% FSF with 100% oats grain

Experimental Feeds and Feeding Management

Naturally ripen and dry FSF were collected from fig trees in Horro district, western Ethiopia, packed in clean sacks and taken to Haramaya University sheep farm. The fruits were further sun dried to ensure grinding of the feed in conventional flour mill. The OG was purchased from Sheno town of North Shoa zone of Oromia National Regional State, ground in similar mill and taken to sheep farm where FSF were stored. The two feeds were used as energy supplement and mixed at different proportions as shown in Table 1.

During the study, sheep were allowed to adapt with the treatment diets for two weeks. After completion of adaptation period, they were offered measured quantity of the diets. Clean tap water was provided in a bucket and changed whenever contaminated with feces or feed material. The basal diet (natural pasture hay) and concentrate supplement were offered in a separate feeding material. The amount of feeds offered and refused was measured and recorded every day. The basal diet offer was adjusted at interval of 3 days for *ad libitum* intake at 20% refusal. The live weight change of the animals was recorded every fortnight. The experiment lasted for 90 days.

Chemical Analysis of the Experimental Diets

The chemical analysis of the basal diet and the concentrates were performed at Haramaya University Animal Nutrition laboratory. During the feeding periods, feed samples were taken each day and bulked in a separate bag. At the end of the feeding trial, the feed in the bag was thoroughly mixed and ample sample was processed for chemical analysis in the laboratory.

The samples were partially dried in a forced draft oven at 65^{o}C to constant weight. The dried samples were ground to pass a 1mm sieve size Wiley mill and collected into a labeled crucible and placed in desiccators to equilibrate with air at room temperature. The samples were then put in air tight plastic bag and kept in the laboratory until required for further analysis. The chemical analysis for each sample was run in duplicate. When the difference between the duplicates exceeds 5%, the analysis was repeated. The dry matter (DM) and ash contents of the feed samples were determined following the procedure of AOAC (1995). The NDF, ADF, and ADL were determined based on the method described by Van soest and Robertson (1985). Hemicelluloses and cellulose were calculated as NDF-ADF and ADF-(ADL+ADF ash), respectively. The ME (MJ/kg) of the diets was estimated according to the procedure described by Moran (2005). The nitrogen (N) content of the samples was determined by the micro-Kjeldahl method and CP was calculated as N X 6.25.

Carcass Measurements and Chemical Analysis

At the end of the feeding trial, all sheep were fasted overnight, weighed, and slaughtered. On slaughtering, the animals were killed by cutting their jugular vein and carotid artery with knife. Their blood was taken in separate container and weighed. During slaughtering process, data were carefully recorded and the carcass was dismembered into its component parts namely, loin, forelegs, hind legs, brisket, rib with muscle, neck, and tail fat. The non-carcass components were also partitioned into edible viscera, which include blood, empty gut, heart, heart fat, liver with gall bladder, kidney, kidney fat, tail, omental and intestinal fat, and tongue and non-edible viscera, which is represented by gut content, penis with fat, spleen, testicles, lungs, trachea, esophagus, head without tongue, limbs, and skin. The edible and non-edible components of the viscera were identified according to meat eating habit in the country. Digital balance was used for weighing carcass and organs.

The empty body weight (EBW) was calculated as the difference between slaughter weight (SW) and gut content, skin and limbs. Dressing percentage was calculated as the percentage of HCW from SW. The rib-eye area (REA), both the right and left halves, were cut between the 12th and 13th ribs perpendicular to the backbone to measure the cross sectional area of the rib-eye muscle. The rib-eye muscle area was traced on transparency paper and the area was drawn using permanent ink marker. Then this transparent paper was traced on graph paper and the area was measured by calculating the area of the squares on the graph paper and multiplying by the number of the squares in the area. The average of the left and the right *longisimus dorsi* muscle cross-sectional area was recorded for each animal.

The DM and ash contents of the carcass samples were determined following AOAC (1995). The moisture content was determined by weight difference before and after drying the carcass sample at 100^{o}C to constant weight. The proximate composition of the sample for ether extract (EE) and crude fiber (CF) were determined according to AACC (2000). The N content was determined by the micro-Kjeldahl method and crude protein (CP) was calculated as N*6.25.

Carcass pH Measurement

The *longisimus dorsi* muscle (10g) was taken as duplicate sample, and cut into small pieces finely and uniformly. The samples were filled into a clean beaker of 100 ml volume to a depth of 4cm. About 10 ml of distilled water was added to each sample and homogenized for one minute and left to rest until the equipment was adjusted to working temperature. The electrode of Demetra model PM 53D portable pH meter was vertically submerged into the solution to a depth of 2cm avoiding contact of the probe with fat and connective tissues and hold for 30 seconds until the reading became stable. The electrode was cleaned with distilled water between sample measurements. The pH reading for all samples was taken at 45min and 6, 12, 18, and 24 hours following evisceration of the carcass.

Statistical Analysis

Data on carcass yield and compositions were analyzed using the General Linear Model of the statistical analysis system (SAS) (2008) procedure. Treatment means were compared using Tukey honestly significant difference test. The data and graphics on pH concentration of the *longissimus dorsi* muscle were summarized, described and plotted using excels spreadsheet. The model for the analysis of carcass yield and composition was:

$$Y_{ijk}=\mu + \tau_i + \beta_j + \varepsilon_{ijk}$$

where, μ=overall mean of the population; τ_i= ith treatment; β_j= jth block and ε_{ijk}=random error

RESULTS

Nutrient Composition of Major Experimental Diets

As depicted in Table 1, DM and CP contents of the experimental diets are similar. The ash content was higher in the control diet and consistently decreased with decreasing level of FSF in the diet. The NDF, ADF, cellulose, hemicelluloses and lignin contents were higher in the control than in the supplemented diets and these were in opposite trend of the ash levels in the diet. On the other hand, the ME content was lower in the control than in the supplemented diets and increased with increasing level of FSF in the diet.

Carcass Yield and Primal Cuts

The effect of supplementing Hararghe highland sheep with dried and ground FSF is presented in Table 2. Although there was numerical difference between the control and treatment diets (100FSF, 67FSF, 33FSF, and 0FSF), the analysis of variance did not show significant difference (P>0.05) for all carcass parameters studied. Animals consumed the control diet had numerically lower slaughter measures and carcass cuts than the average of the other treatments. Among the treatment diets, 100FSF resulted in relatively higher magnitude of slaughter and hot carcass weight, and dressing percentage compared to other treatment diet.

Table 2: Carcass yield and primal cuts of Hararghe highland lambs fed a basal diet of natural pasture hay supplemented with different proportions of FSF and oats grain

Carcass measurements	Treatments					SEM	SL
	control	100FSF	67FSF	33FSF	0FSF		
Slaughter characteristics							
Slaughter weight (kg)	16.1	18.3	18.4	17.4	16.9	0.98	ns
Empty body weight (kg)	11.4	13.8	13.7	13.2	12.2	0.91	ns
Hot carcass weight (kg)	6.08	8.0	7.72	7.26	6.83	0.61	ns
Dressing percentage (%)	37.7	43.1	41.8	41.7	40.1	1.65	ns
Rib-eye-area (cm^2)	6.48	6.67	6.87	6.10	6.29	0.42	ns
Carcass cuts (kg):							
Loin (kg)	1.28	1.40	1.47	1.31	1.27	0.13	ns
Forelegs (kg)	1.16	1.45	1.47	1.31	1.41	0.09	ns
Hind legs (kg)	1.58	1.89	1.84	1.69	1.71	0.14	ns
Brisket (kg)	0.52	0.72	0.62	0.64	0.59	0.06	ns
Rib-with-muscle (kg)	1.00	1.18	1.05	1.09	0.89	0.11	ns
Neck (kg)	0.58	0.75	0.68	0.61	0.62	0.05	ns
Tail fat (kg)	0.38	0.72	0.70	0.62	0.65	0.09	ns

FSF=*Ficus sur* fruits; 100FSF= 100%FSF and 0% MG;67FSF= 67% FSF and 33% MG; 33FSF=33% FSF and 67% MG; 0FSF= 0%FSF and 100% MG; control diet=natural pasture hay; SEM = Standard error of the mean; ns= non-significant; SL=significance level.

Non-carcass Components

Edible Non-carcass Components

Consistent with carcass parameters, there was no difference (P>0.05) in most edible non-carcass components among the dietary treatments compared (Table 3). However, liver with gall bladder, kidney, reticulo-rumen, and omentum and mesenteric fats showed significant difference (P<0.05) among the treatments and the control diets. The relative weight of liver with gall bladder and reticulo-rumen were significantly (P<0.05) higher in 0FSF compared to animals consumed the control whereas, the weight of the kidney and omentum and mesenteric fat were highest for 67FSF.

Table 3: Non-carcass edible component of Hararghe highland lambs fed a basal diet of natural pasture hay supplemented with different proportions of FSF and oats grain

Edible offal components (kg)	Treatments					SEM	SL
	control	100FSF	67FSF	33FSF	0FSF		
Blood	0.54	0.58	0.58	0.56	0.54	0.04	Ns
Empty gut	0.937	1.01	1.11	1.02	1.11	0.07	Ns
Heart	0.06	0.08	0.07	0.07	0.07	0.03	Ns
Heart fat	0.13	0.03	0.03	0.12	0.26	0.05	Ns
Liver with gall balder	0.18^{b}	0.19^{ab}	0.23^{ab}	0.24^{ab}	0.25^{a}	0.02	*
Kidney	0.04^{b}	0.05^{ab}	0.06^{a}	0.05^{ab}	0.05^{ab}	0.01	*
Kidney fat	0.04	0.04	0.04	0.05	0.03	0.01	Ns
Reticulo-rumen	0.36^{b}	0.41^{ab}	0.44^{ab}	0.43^{ab}	0.48^{a}	0.02	*
Omentum and mesen. fat	0.04^{b}	0.06^{ab}	0.13^{a}	0.07^{ab}	0.07^{ab}	0.02	*
Omaso-abomasum	0.13	0.13	0.16	0.14	0.14	0.01	Ns
Tongue	0.05	0.06	0.06	0.06	0.07	0.01	Ns
Small Intestine	0.28	0.30	0.31	0.33	0.36	0.02	Ns
Large-Intestine	0.16	0.17	0.19	0.18	0.19	0.02	Ns
TEOC	2.93	3.16	3.47	3.22	3.37	0.16	Ns

[ab]Means with different superscript letter in the same row differ; FSF=*Ficussur* fruits; 100FSF= 100%FSF and 0% MG; 67FSF= 67% FSF and 33% MG; 33FSF=33% FSF and 67% MG; 0FSF= 0%FSF and 100% MG;control diet=natural pasture hay; SEM = Standard error of the mean; ns= non-significant; SL=significance level; 100FSF = 100% FSF with 0% oats grain; 67FSF= 67% FSF with 33% oats grain; 33FSF= 33% FSF with 67% oats grain; 0FSF= 0% FSF with 100% oats grain

Non-edible Non-Carcass Components

The treatment diets did not affect (P>0.05) the non-edible non-carcass components, except penis with fat and esophagus, which showed difference among treatments, but with no consistent trend (Table 4).

Table 4: Non-edible non-carcass component of Hararghe highland lambs fed a basal diet of natural pasture hay supplemented with different proportion of FSF and oats grain

Non-edible offal components (kg)	Treatments						
	control	100FSF	67FSF	33FSF	0FSF	SEM	SL
Head without tongue	1.13	1.17	1.22	1.29	1.28	0.05	Ns
Limbs	0.36	0.41	0.44	0.42	0.45	0.02	Ns
Skin	1.75	1.99	2.46	2.25	2.32	0.24	Ns
Gut content	4.67	4.25	4.70	4.58	4.74	0.39	Ns
Penis with fat	0.06^{b}	0.08^{ab}	1.08^{ab}	1.10^{a}	0.08^{ab}	0.01	*
Spleen	0.05	0.03	0.03	0.03	0.03	0.01	Ns
Testicles	0.15	0.19	0.20	0.23	0.20	0.02	Ns
Lungs	0.14	0.19	0.19	0.17	0.21	0.01	Ns
Trachea	0.07	0.07	0.06	0.05	0.08	0.01	Ns
Esophagus	0.02^{b}	0.03^{ab}	0.03^{a}	0.03^{a}	0.04^{a}	0.01	***
TNEOC	8.42	8.40	9.43	9.16	9.43	0.66	Ns

^{ab}Means with different superscript letter in the same row differ; FSF=*Ficus sur* fruits; 100FSF= 100% FSF and 0% MG;67FSF= 67% FSF and 33% MG; 33FSF=33% FSF and 67% MG; 0FSF= 0%FSF and 100% MG; control diet=natural pasture hay; SEM = Standard error of the mean; ns= non-significant; SL=significance level

Carcass Composition

Animals fed with sole FSF (100FSF) had the highest carcass DM and CP followed by 67FSF, except for ether extract (Table 5). Animals fed with 33FSF and 0FSF had similar carcass DM and CP, which is significantly higher (P<0.05) compared to the control. The DM composition of the carcass tended to consistently increase with increasing levels of FSF in the diets.

Table 5: Chemical composition of carcass of Hararghe highland sheep fed a basal diet of grass pasture hay supplemented with different proportions of FSF and oats grain

	Dietary treatments						
Composition (% DM)	control	100FSF	67FSF	33FSF	0FSF	SEM	SL
Moisture	69.8^{c}	72.7^{a}	71.3^{b}	70.1^{c}	69.4^{c}	0.21	***
Dry matter	30.6^{a}	27.3^{c}	28.7^{b}	29.9^{a}	30.6^{a}	0.20	***
Total ash	2.07	2.03	2.37	2.27	1.93	0.26	ns
Ether Extract	4.87^{b}	5.31^{b}	6.27^{a}	6.57^{a}	6.77^{a}	0.15	***
Crude Protein	19.4^{c}	21.5^{a}	21.2^{a}	20.4^{b}	20.1^{b}	0.09	***

^{ab}Means with different superscript letter in the same row differ; FSF= *Ficus sur* fruits; 100FSF=100%FSF and 0% MG; 67FSF=67% FSF and 33% MG; 33FSF=33% FSF and 67% MG; 0FSF=0%FSF and 100% MG; control diet=natural pasture hay; SEM=Standard error of the mean; ns= non-significant; SL=significance level. ***= P<0.001

Carcass pH

Table 6 indicates the effect of dietary treatments on pH values of sheep carcass at different hours. The overall mean carcass pH was significantly different (P<0.0001) among the treatments.

Table 6: Effect of dietary treatments on pH values of sheep Carcass at different post-evisceration hours

pH after*	Dietary treatments					SEM	SL
	Control	100FSF	67FSF	33FSF	0FSF		
O hours	7.8^{a}	6.9^{d}	7.2^{c}	7.3^{bc}	7.4^{b}	0.036	***
6 hours	7.0^{a}	6.3^{d}	6.6^{c}	6.7^{bc}	6.8^{b}	0.035	***
12 hours	6.6^{a}	5.9^{d}	6.2^{c}	6.3^{bc}	6.4^{b}	0.036	***
18 hours	6.2^{a}	5.6^{d}	5.9^{c}	6.0^{bc}	6.1^{b}	0.035	***
24 hours	6.0^{a}	5.3^{d}	5.7^{c}	5.8^{bc}	5.9^{b}	0.036	***

^{abc}Means with different superscript letter in the same row differ; *0 hour= 45 min post-evisceration; FSF=*Ficus sur* fruits; 100FSF=100%FSF and 0% MG; 67FSF=67% FSF and 33% MG; 33FSF=33% FSF and 67% MG; 0FSF=0%FSF and 100% MG; control diet=natural pasture hay; SEM=Standard error of the mean; ns= non-significant; SL=significance level.

The pH consistently decreased with increase in time after evisceration irrespective of the difference among the treatments (Figure 2). However, carcass pH was slightly lower for lambs supplemented with different proportions of FSF compared to the control. Among dietary treatments, animals in 100FSF maintained the lowest carcass pH throughout the measurement time followed by 67FSF.

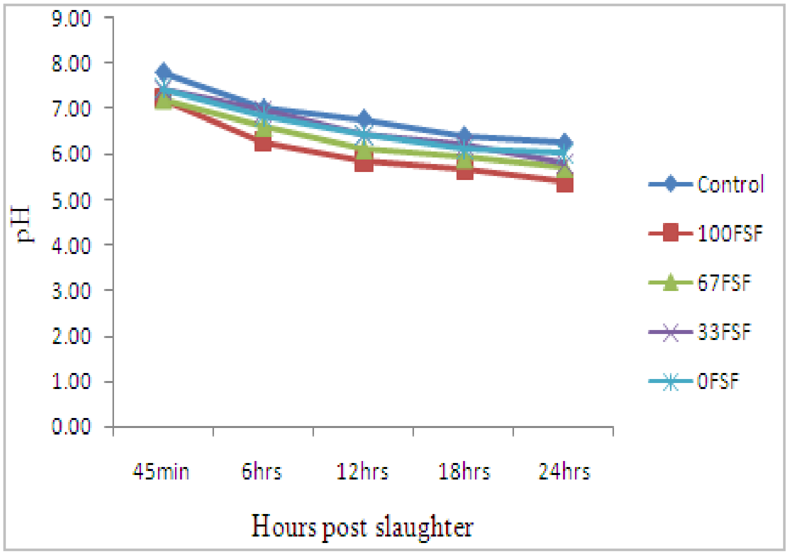

Figure 1: pH concentration of carcass of lambs fed with different proportion of *Ficus sur* fruits and oats grain across post-evisceration time

DISCUSSION

Nutrient Composition of Experimental Feeds

Although OG contained more OM, the relatively higher ADF composition of OG than in FSF may presumably reduce its digestibility (McDonald *et al*., 2002). Moreover, the higher NDF value in OG could influence voluntary feed intake and its efficiency to support the proliferation of rumen microbes due to its lower readily fermentable nutrients than FSF. This implies that OG may negatively influence the digestibility of the fibrous basal diet and its utilization making it less worthy than FSF in improving animals' performance. In another word, FSF had higher neutral detergent soluble (68.07%) than OG (60.22%) that could support rumen microbes as sources of soluble carbon. Thus, FSF could be an important alternative energy supplement than OG to animals as depicted by its chemical concentration as well as less competition for FSF with human as food than OG.

Carcass Yields and Primal Cuts

The absence of statistically significant difference in carcass yield and cut values between the control and other treatments could be an attribute of supplementation of all animals with isonitrogenous diets. Supplementation of NSC could have made sufficient amount of protein source available to the rumen microbes to proliferate, thereby enhanced the utilization of nutrients in the hay by the animal (Krebs *et al*., 2007; Ben Salem *et al*., 2002). Burrin (2002) noted that some dietary essential amino acids and nearly all of the nonessential amino acids are converted to energy in the first compartments of the small intestine, when animals consume feeds deficient in energy. Such mechanisms must have helped the lambs to compensate the energy limitations in the control diet. Nevertheless, the lower carcass yield and cut values for sheep that consumed control diet indicates that supplementation of FSF, OG or their mixture had improved performance of the lambs.

The higher dressing percentage in 100FSF could be an attribute of the higher hot carcass weight (8kg) compared to 0FSF (7.26kg) and the higher offal content in 0FSF than 100FSF, since dressing percentage in this particular study was calculated with slaughter weight as a numerator than empty body weight. The higher mean carcass yield in sheep consumed 100FSF implies that supplementation of FSF have improved the meat production of Hararghe highland sheep as compared to OG diets. The result of carcass yield in the present study was 40.6% more than the carcass yield obtained from rams managed under farmers' conditions (Kefyalew *et al*., 2013), but similar with carcass obtained from the same breed of lambs supplemented with 350 g commercial concentrate mix to a basal diet of urea treated maize stover (Hirut *et al*., 2011). The Dressing percentage obtained in the present study fall within a range (36.7-45.2%) reported for other indigenous sheep breeds supplemented with different diets (Takele and Getachew, 2011; Getnet *et al*., 2008; Jemal *et al*., 2005)

Edible and Non-edible Offal Components

The feeds the animals consume affect not only the growth of live body weight and carcass, but also mass of all viscera organs (Lawrence and Fowler, 2002). In the present study, the development of the majority of the organs remains similar. This similarity between the growths of most viscera organs could be due to the fact that these organs develop at early age of the animals (Yun *et al*., 2003) and less influenced by supplementation. Since the diets used in the study contain low levels of plant secondary metabolites, higher weight of the liver and kidney displayed in OFSF treatment group than the control may not be related to toxic effect of the diet (Getnet *et al*., 2008), rather it may be associated to less glycogen store or slower development of this organs in lambs fed the control diet. The higher growth of gut for lambs consumed maximum OG levels (0FSF) might have been due to higher fiber content of the diets (OG). High fiber diets having large amounts of undigested material entering the small intestine result in net tissue growth. Fluharty *et al*. (1999) also noted higher GIT organs weight growth in lambs' grazed alfalfa dominated high fiber pasture than those consumed mixed concentrate diets. The result for TEOC in the present study (range, 3.16-3.47%) was higher than obtained by Tsehay (2012) in Hararghe highland sheep (2.7-3.2%) fed a basal diet of natural pasture hay and supplemented with graded levels of onion leaves as a substitute for wheat bran in concentrate mixture. But, it falls within a range (2.22 kg – 4.19 kg) reported by Hirut *et al*. (2011) in the same sheep breed fed urea treated maize stover basal diets supplemented with different concentrate mixture. Similar to the present study, Malisetty *et al*. (2013) reported significantly different weight of edible organs in Nellore ram lambs consumed maize silage basal diets and supplemented with different levels of concentrate, while Madhavi *et al*. (2006) noted no considerable difference between edible viscera organs for this breed of ram lambs fed differently processed detoxified neem (*Azadirachta indica*) seed cake based complete diet.

Evaluation of non-edible organs may help in the diagnosis of abnormal physiology that indirectly influences the status of the edible viscera or carcass components. For example, pancreas is a viscera organ where most digestive enzymes and hormones are secreted (McDonald *et al*., 2002) and hence affects all the organs' system performance. In the present study, there was no abnormal increase or decreases in the size of any of the non-edible viscera organs. The total non-edible offal component ranged 8.42 kg-9.43 kg was slightly higher than the same breed of sheep (8.09 kg-8.39 kg) fed urea treated maize Stover supplemented with concentrate mix (Hirut *et al*., 2011). Generally, lambs fed with the treatment diets recorded higher weights of edible and non-edible organs, at least in magnitude, than control diet. Thus, supplementing FSF to Hararghe highland lambs fed with natural pasture basal diets could produce higher offal than the non-supplemented groups.

Carcass Composition

The variation in nutrient composition of feeds consumed by animals affects carcass composition (Plam, 2004) and thereby sensory quality of meat (Melton, 1990). Higher moisture content of carcass enhances microbial growth for spoilage, and reduces shelf life and taste of meat (Lawrie and Ledward, 2006).The moisture contents of the carcass in the present study were within the normal range for lambs (Santoso *et al*., 2008; Hui *et al*., 2001). Nevertheless, higher moisture content in treatments supplemented with concentrate containing high level of FSF may be an indication that use of this feed resource at high level than the present may impart some undesirable properties to the carcass.

The increase in ether extract with increased level of OG in the present study could be due to higher fiber content of OG than FSF. Feeds with high fiber results in more volatile fatty acids production in the rumen and enhance mutton fat, thereby the crude fat percentage of the carcass. Optimum fat content of meat improves juiciness, flavor, and texture, but if the level increases above optimum, it negatively affects the flavor due to production of volatiles (Melton, 1990). This may raise blood cholesterol level, a risk factor for cardiovascular disorder. The optimum lipid value for meat is 5% of the carcass (Hui *et al*., 2001), which was nearly similar with the EE content of lambs (5.3%) fed 100FSF, unlike the 6.7% for those fed with 0FSF (100% OG) in the present study. The EE value of all lambs in the present study was less than the value (14.8-25.7%) reported by Kiyanzad (2005) for lambs of different breeds. Moloney *et al*. (2002) and Chan *et al*. (1995, 1996) noted fat content of 7.5-9.4% in lamb meat to be normal for consumption in human diets. The fact that fatty acids and fats are components of ether extract (crude fat); the low value for EE percentage (4.87-6.77%) observed in the present study is an indicator of meat quality from this breed of lambs.

The CP content of mutton in the present study is higher than the value reported in earlier studies (13.4-18%; Kiyanzad, 2005). The consistent increase in crud protein (CP) content of the meat with increasing level of FSF inclusion indicates the leanness of the meat in groups fed with FSF containing diets than the sole oat grains. This could be due to higher protein to energy ratio in the lower digestive tract of the lambs. Moreover, the readily soluble energy nutrients of the FSF might have contributed to the proliferation of the rumen microbes, which produced quality microbial protein available for lower gut digestion and absorption, thereby improving lean muscle development in meat, which is the most preferable characteristic in mutton.

Carcass pH Concentration

The main factor determining the quality of meat is its pH, because it is related to biochemical processes during the transformation of muscle to meat (Bas *et al*., 2000). Consequently, changes in the pH during the *post-mortem* period influence the organoleptic characteristics of the meat. All the readings of pH in the present study fall within the range of 7.42 to 5.84 when measured at initial time of 45 minutes and 24 hours post-evisceration, respectively indicating that the pH of meat consistently decreased with time due to progress in lactic acid production as expected naturally. Hence, it was shifted from slightly alkaline to acidic condition. After 24 hours of evisceration, only 100FSF (5.41) and 67FSF (5.71) resulted in values, which are considered optimum meat pH (Ameha, 2008).

The pH of mutton from lambs consumed control diets is high compared to all other treatment diets. This could presumably be due to relatively lowest glycogen reserve in their *longisimus dorsi* muscle that can result in lactic acid production for the reduction of the pH. At pH of 5.4-5.5 the post mortem glycolysis may still contain as much as 1800 mg residual glycogen/100 g muscle. This can increase the water-holding capacity and tenderness of the muscles when cooked (Immonen *et al*., 2000). On the other hand, Lawrie and Ledward (2006) noted that residual glycogen does not exist if the pH fails to less than 5.4 during post-mortem glycolysis. Similarly McIntyre (2000) suggested that muscle pH value above 5.7 is unacceptable and results in rigor and stiffness of *longisimus dorsi* muscle. According to Ameha (2008) good quality meat usually has a pH of 5.4–5.7 when determined at 45 minutes post slaughter.Young (2001) suggested that meat pH above 5.9 has bad storage value for two reasons: First putrefactive bacteria such as *Shewanella putrefaciens* and *Yersinia enterocolitica* are able to grow anaerobically on meat and second, the glucose concentration is lower as pH increases. When glucose becomes absent due to microbiological activity, the microflora begin to use amino acids as an energy source, generating offensive catabolic products. Therefore, the pH that occurred in sample from lambs fed with 100FSF at 18 hours and 67FSF at 24 hours indicate that desired meat characteristics with longer shelf life can be obtained by feeding lambs with 100FSF diet.

CONCLUSION

This study demonstrated that inclusion of FSF in the diet of Hararghe highland lambs as a replacement for oat grains improved carcass yield and quality, particularly at higher level of inclusion. Hence, it can be concluded that FSF can be used as energy supplement for sheep and can replace oat grain or other concentrate with similar composition for use in small holder sheep production systems.

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Conflict of Interest

Conflict of Interest None declared

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