Feed utilization, digestibility and carcass parameters of Tigray highland sheep fed wheat straw supplemented with mixtures of wheat bran and cotton seed cake, in Tigray, Ethiopia

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Abstract

The experiment was carried out at Mekelle University livestock farm, Tigray, Ethiopia. Twenty four male yearling Highland sheep with an average live weight of 16±2.4kg (mean ± standard deviation) were used in the experiment. The objective of the study was to investigate the effect of concentrate supplementation with mixtures of wheat bran (75%) and cotton seed cake (25%) on performance of highland sheep. The experimental design was a randomized complete Block design (RCBD) with four treatments and six replications. The experiment was carried out for 90 days after 21 days of feed adaptation period. At the end of the feeding trial digestibility trial was carried out for seven consecutive days followed by evaluation of carcass parameters. There was significantly higher ($P<0.05$) total DM intake in the supplemented group than the control treatment. Similarly, there was a significant difference ($P<0.05$) among all treatments in CP intake due to the increased level of supplementation. Digestibility of DM, OM and CP were also significantly higher ($P<0.05$) for rams supplemented with the higher level of concentrate mixture than the control treatment. The feed conversion efficiency was significantly ($P<0.05$) higher for the high level of supplement as compared to the other treatments. The mean values of slaughter weight, empty body weight and rib-eye area were significantly ($P<0.05$) higher for the 200 and 250 g/d supplemented treatments than the control Generally the present study indicated that supplementation of Tigray highland rams with concentrate mixture had an effect on performance of sheep and the effects were relatively more pronounced on rams supplemented with the highest level of concentrate mixture. Therefore, supplementation of WS with 250g DM concentrate mixture is biologically more efficient.

Keywords: cotton seed cake, highland rams wheat bran and wheat straw.

Introduction

The estimated livestock population of Ethiopia is 38.7 million cattle, 16.1 million sheep, 14.9 million goats, 5.8 million equine and 0.46 million camels (CSA, 2005). Livestock provide milk, meat, manure, hides and skins; they are also a source of draught power mainly in the highlands of Ethiopia, where crop-livestock farming is the dominant production system (ILRI, 1995). Despite the large livestock population size, their productivity is low with 8 kg of beef produced annually per head of cattle and with an average milk yield of 1.23 liters per cow per day (CSA, 2005). The causes for low productivity of livestock in Ethiopia are multifaceted that include poor genetic makeup, poor veterinary services, inadequate quantity and quality of feed, and poor breeding strategy.

Among these limiting factors, poor feed supply and feeding system is the most important as the feed resources in the highlands of Ethiopia are generally natural pasture and residues of different crops. McDonald *et al*. (2002) confirmed that all the straws and related by-products are extremely fibrous, most of them have a high content of lignin and all are of low nutritive value. In addition to this, most dry forages and roughages found in Ethiopia have a crude protein (CP) content of less than 7 % which indicates microbial requirement can hardly be satisfied unless supplemented with protein rich feeds (Vansoest *et al*. 1994). When fed alone, such feeds are unable to provide even the maintenance requirement of livestock (FAO/ILRI, 1999). Moreover, the rapid increase in human population puts pressure on the land for crop production; resulting in less and less land available for grazing and leading to an increase feed shortage (Gemeda *et al*., 2003).

Meat demand of consumers cannot be satisfied and the current high price for meat can not be maintained with the ever-increasing human population. Hence, the livestock sector has to look for mechanisms to balance the demand & supply of meat. In this regard, small ruminants can provide an opportunity being small in size, having high reproduction rate, and their ability to thrive on locally available and low quality feeds. As Continued feeding low quality feed stuffs like straws will not benefit in increasing the rate of live weight gain and animal off take, from the pastoralists as well as smallholder livestock production system. Therefore, it is important to consider the improvement of the feeding system for livestock. In this case, the use of supplementation of straw with agro-industrial by-products need due attention. One possible method of improving the nutritive values of crop residues is through strategic supplementation with energy and protein source that can promote feed intake and digestibility (Melaku and Nega, 2008). Hence, there is a need to search for alternative available feed resources, which could supplement poor quality roughage feeds to enhance productivity of livestock in the tropics. In this regard, agro-industrial by-products that are rich in energy and CP, and not directly used in human diets offer an opportunity in improving the feeding of sheep. These feed resources including flour milling by-products such as wheat bran (WB), and edible oil extraction by-products such as cotton seed cake (CSC), noug seed cake (NSC), etc.

Materials and Methods

Study site

The experiment was conducted at Mekelle University Small Ruminants Farm Unit, located 783 km North of Addis Ababa. The site lies at an altitude of 2250 masl l3^{0} 28' N latitude and 39^{0} 29' E longitudes. The mean annual rainfall is 680 mm; the mean annual maximum and minimum temperatures are 26.4 ^{0}C and 8.25 ^{0}C, respectively (BOANR 1997).

Experimental Feed Preparation

The supplement feeds, cotton seed cake and wheat bran, used for the experiment were purchased from local market and Quiha wheat flour milling factory, respectively. The basal diet (wheat straw) was obtained from Mekelle University Livestock farm. They were stored in a clean feed storing house which was in convenient for microbial growth. The supplement feed were thoroughly mixed at the given proportion after proper grinding of the cotton seed cake.

Experimental Sheep

Twenty four yearling highland growing rams weighing 16 ± 2.4 kg (mean ± Standard deviation) were purchased from Mekelle (*Edaga Sonuy*) local markets based on their dentition and information from the owners. The animals were drenched with a broad spectrum anathematic (Albendazol) drug against internal parasites and sprayed (Accaricide / Ectoparasite) against external parasites. They were vaccinated against common diseases (anthrax and pasteurelosis) during the quarantine period. Then the experimental animals were housed in individual pens and offered WS and the supplements (cotton seed cake and wheat bran mixtures) for 21days to get them adapted to the feeds prior to the beginning of the experiment. Animals were closely observed for the occurrence of any ill health and disorders during the experimental period. The wheat straw (WS) was fed to the experimental animals *ad libitum.* The animals had access to water and common salt licks on *ad libitum* basis. Except the control animals, those in the other treatments were supplemented with the respective level of concentrate mixture at 0800 and 1600 hours in two equal portions.

Experimental Design and Treatments

The treatments comprised of different levels of concentrate mixes formulated according to the growth requirements of the sheep based on the recommendations of the National Research Council (NRC, 1981) and by considering their body weight and the expected weight gain. The concentrate mixture comprised wheat bran and cotton seed cake with the ratio of 3:1 on DM bases, respectively. The experimental treatments included offering the concentrate mixture at 0 g, 150 g, 200 g and 250 g head/day on DM bases. The supplement feeds were offered in two equal portions twice a day at 0800 h and 1600 h. The experiment was conducted for 90 days of feeding trial and 7 days of digestibility trial.

The experiment was conducted using a randomized complete block design (RCBD) with four treatments and six replications. The experiment sheep were blocked based on their initial weight in to six blocks of four animals each. A mean of two consecutive live weights were taken after overnight fasting to determine initial weight of animals Treatment diets were randomly assigned to each animal in the treatment in such a way that each animal had equal chance of receiving one of the treatment diets.

Measurements

Chemical Analysis

Representative samples of daily feed offers, refusals and feces were ground to pass through a 1 mm sieve screen size. The ground samples were analyzed for contents of DM, ash, and nitrogen. Sample of urine also analyzed for content of nitrogen using the procedure of AOAC (1997). The CP was computed as N x 6.25. The crude fiber (CF), acid detergent fiber (ADF), and acid detergent lignin (ADL) were analyzed following the procedure of (Van Soest et al 1994).

Statistical Analysis

The data obtained from the experiment were analyzed using descriptive statistics, correlation, ANOVA by the business unit of SAS, JMP5. The treatment means of the parameters were separated using Tukey HSD (Tukey Honestly Significant Difference) Test. The model used for the analysis of all parameters feed intake, weight gain, digestibility, and carcass parameters of the experiment was:

$$Y_{ij} = \mu + \alpha_i + \beta j + \varepsilon_{ij}$$

Where: Y_i = response variable, μ = overall mean, α_i = i^{th} treatment effect, βj = block effect and ε_{ij} = i^{th} random error

For the analysis of carcass parameters the slaughter weight (kg) was added as a covariate in the above statistical model and was kept if it reached significance.

Feed intake

For each animal, daily offered and refusal of each treatment diet was measured and recorded throughout the experiment for 90 days. Samples of feeds offered were collected on batches of feeds and that of refusals were collected for each animal and pooled for each treatment. Daily feed intake of individual sheep was recorded as a difference between the feed offered and the refusal. The substitution rate was calculated by the equation adapted from Ponnampalam *et al*. (2004) as given below:

$$\text{Substitution rate} = \frac{\textit{WS intake of basal diet} - \textit{WS intake of the supplemented treatment}}{\textit{Concentrate intake}}$$

Digestibility trials

After the completion of ninety days feeding trial, a digestibility trial was conducted with the same animals and rations of the feeding trials. The digestibility and N balance of the experiment was conducted by keeping the animals in an individual metabolism cage permitting separate collection of urine and feces and equipped with feeders and water supplies. The animals were placed in their individual metabolic cage to which animals were adapted the carrying of fecal bags for three (3) days. This was followed by total collection of feces and urine for seven days.

Collection and Storage of Feces and Urine

Feces and urine from each animal were collected separately each day at the same time just prior to offering water and feeds. The total daily-excreted feces of each animal was weighed and recorded. The feces were mixed thoroughly and 10% was daily pooled for the experimental period per animal. A 100 ml of (10%) sulfuric acid was added to each urine collection buckets daily to trap the nitrogen that may escape as ammonia from the urine. Twenty percent of the urine-voided daily per animal was sampled and pooled over the collection period. Feces and urine samples were stored at (-20^{0}C) for analysis. The composite fecal samples were thawed to room temperature and dried at (65^{0}C) to a constant weight. Dried samples were ground through a 1 mm sieve and preserved for chemical analysis. The digestibility coefficients (DC) of nutrients were calculated by using the following equation (McDonald *et al.* 2002)

$$\text{DC(\%)} = \frac{\text{Total amount of nutrients in feed - total amount of nutrients in feces}}{\text{Total amount of nutrient in feed}} \times 100$$

The N intake from WS and concentrate was determined by multiplying the DM intake of the WS and concentrate with the corresponding N content of each feed. The total N intake was determined as the sum of the N intake from the WS and supplement. Nitrogen retention was calculated as a difference between the N intake and N excretions (fecal and urinary) during the seven days of collection.

Carcass parameters

At the end of the feeding and digestibility trial, four experimental animals from each feeding treatment were fasted overnight and slaughtered. Slaughter weight (SW) was taken 30 minutes before slaughter. Pre-slaughter body weights, hot carcass weights, empty body weight and rib eye (*longissimus dorsi*) area were measured. The weights of the kidney and omental fat deposits and of the major internal organs (lungs with trachea and esophagus, heart, kidneys, and liver with gall bladder, spleen and pancreas, testis and penis), the entire alimentary canal (full stomach, and empty gut), skin with feet, tail, blood and head with tongue were recorded separately using sensitive balance weighing from 0.00g to 5 kg.

The carcass was partitioned into hind and fore quarter between 9th and 10th ribs. The four ribs from (10th to 13th) were chilled overnight in deep freezer and the rib eye (*Longissimus dorsi*) area (cm^2) was measured at the 11th and 12th rib site (Gallal *et al*., 1997a). The rib-eye area value was the mean of the left and right sides. The cross sectional area of the rib eye muscle (*longissimus dorsi*) area was traced first on plastic paper after it was cut at the 11th and 12th ribs perpendicularly to back bone. The rib-eye area was again traced on graph paper and computed using mechanical polar planimeter (model series 20) and cross checked with graph paper squares each with a size of 1mm x 1mm. The area of the squares that fall within the tracer mark was then counted on both sides and the average of the two sides was used to calculate rib-eye area in cm^2.

Empty body weight was determined by reducing the gut fill from slaughter body weight. Dressing percentage was calculated on the bases of slaughter and empty body weight using the formula:

$$\text{Dressing Percentage} = \frac{Hot\,carcass\,weight}{Slaughter\,body\,weight} X100 \quad \text{(and)} = \frac{Hot\,carcass\,weight}{Empty\,body\,weight} X100$$

The hot carcass weight was calculated in two ways with and without including the tail weight to see the influence of the fat tail of the breeds on dressing percentage value. The dressing percentage on both slaughter and empty body weight bases was also computed accordingly in both ways.

Total edible offal component (TEOC) was taken as the sum of lung with trachea and esophagus, liver with gall bladder, empty gut, visceral fat (kidney fat + omental fat), kidneys, head with tongue and tail. Total non-edible offal component (TNEOC) was computed as the sum of blood, spleen and pancreas, skin with feet, testis and penis and total gut fill. Total usable product (TUP) was taken as the sum of hot carcass weight, TEOC and skin.

Correlation

In the experiment different parameters were correlated using Pearson or product-moment correlation.

Results and Discussion

Chemical composition of experimental feeds

The chemical composition of the experimental feeds indicated that the DM, OM, ASH, CP, CF, ADF and ADL content of the wheat straw (WS) offered was 93.05%, 5.20%, 94.9%, 3.72%, 39.00%, 49.9% and 5.8%, respectively (Table1). The DM content of WS was almost comparable to the values of 91.3% reported by Getahun (2006). The OM and CP content of WS were 94.8% and 3.72%, respectively. This CP content of WS was also comparable with the result reported by Daniel,(1988), which was 4% of DM.The CP content of the wheat straw in this study was below the requirement for maintenance.

The ADF and ADL contents of wheat straw were 49.9% and 5.8%, respectively. The limitation imposed by high fiber content is the reduction in dry matter digestibility leading to in sufficient supply of energy.The CP contents of the concentrate feed ingredients, namely, wheat bran and cotton seed cake were 15.10% and 36.5%, respectively. The mixture of these two concentrates resulted in a CP content of 25.09%. The CP content of wheat bran in this study was comparable to the values of 16.5%, 16.41%, 16.82% reported by Solomon (2004); Awet (2007), and Tesfay (2007), respectively, but lower than the values of 17.19%, and 19.99% reported by Getnet *et al*. (1999) and Alemu (1981), respectively. The variation might be due to the effect of processing in milling industries and the quality of the original grain used in the milling industries.

The CP content of the cotton seed cake in this study was 36.5% of DM. This is higher than the CP content of CSC reported by McDonald (2002) and Seyoum (1995) which was 23.9 and 26.8 %, respectively and lowers than the result reported by Bhuyane *et al*. (1996) and Temesgen (1995), with values of 41.02 and 44.5%, respectively. This difference could be due to the absence of dehulling during the process of oil extraction. The OM contents of different concentrate feeds in the present study such as wheat bran, cotton seed cake and concentrate mixture were 96.05, 94.49 and 91.52%, respectively. The CF (11.99%) and ADF (37.79%) of cotton seed cake in this study were comparable to the values of 10.76 and 35.27% reported by Tesfay (2007), respectively, but lower than the CF and ADF contents of 13.87 and 41.2% reported by Alemu (1981), respectively. The ADF content of cotton seed cake (37.79) and wheat bran (17.82) was almost similar to the result reported by McDonald (2002) 36.2 and 16.9, respectively.

The WS refusals contained lower CP and higher CF, ADF and ADL than in the WS offer in all treatments. This suggests the selective feeding behavior of sheep on portions of feeds with better nutritive value.

Table 1 Chemical composition of the experimental feeds on DM basis

DM=Dry matter; OM=Organic matter; CP=Crude protein; CF=Crude fiber; ADF=Acid detergent fiber;

Nutrients (%)	WB	CSC	Concentrate Mixture	Wheat straw
DM	88.25	89.52	88.94	93.05
Ash	3.95	5.61	8.84	5.20
OM	96.05	94.49	91.52	94.8
CP	15.10	36.5	25.09	3.72
CF	10.43	11.99	10.39	39.00
ADF	17.82	37.79	20.52	49.9
ADL	4.35	6.90	5.46	5.8

ADL=Acid detergent lignin; WB=Wheat bran and CSC = Cotton seed cake.

Feed and Nutrient intake

The mean daily DM intake of WS, total DMI and total nutrients intake with low, medium, and high level of concentrate mixture supplementation is presented in Table 3. From the result a significant difference ($p<0.05$) was observed on the DM and OM intake of WS among treatments. DM and OM intake of WS decreased as the level of supplementation increased Bonsi *et al.,* (1996) reported that supplementation improved the intakes of total DM and OM. The author indicated an increment of 30.6% for the intake of total OM when sheep were fed on teff straw basal diet supplemented with cotton seed cake.

Sheep in the control and lower level of supplementation had consumed more DM and OM of WS as compared to the medium and higher supplemented treatments, might be due to the relatively low CP and high CF content of the WS used in the experiment, and the sheep were seeking to meet their nutrient requirement only through the intake of relatively more WS than the other treatments, which had an alternative source from the concentrate feed. This also indicated that, there was a substitution effect of supplement at the expense of intake of WS. As the level of supplementation increased, there was a depression of WS DM and OM intake. The apparent substitution rate was 0.44, 0.43, and 0.40 for higher, medium and lower level of supplementation, respectively. Type and amount of supplement can affect substitution rate and it has been generally found that substitution rate increases as the level of supplement increases (Ponnampalam *et al.,* 2004).

The total DM intake per unit metabolic body weight of rams in T1, T2, T3, and T4 was 61.18, 62.2, 62.5, and 63.06 g DM per Kg $w^{-0.75}$ respectively and it was in the range of values of 58.6 – 82.2 g DM per Kg $w^{-0.75}$ reported by Bonsi *et a*l.(1996) for Ethiopian sheep. As compared to the control treatment rams with supplemented concentrate mixtures could maximize the total DMI by 14.25, 18.38, and 22.84% for T2, T3 and T4, respectively.

The increased TDMI with increased levels of supplement in the diets also in agreement with the findings of Bonsi *et al*. (1996). Consistent with the present result, supplementation trial on Gwamble goat of Zambia at 0, 50, 100, and 150g peanut cake per animal per day showed that an increase in the level of peanut cake in concentrate mixture, increased total dry matter intake (Bonsi *et al*. 1996). Besides, the DMI and growth rate in Alpine and Nubian goats increased linearly as the level of protein concentration in the diet increased (Bonsi *et al*. 1996).

The CP intake among the different treatment groups was significantly different ($p< 0.05$). There was an increasing trend of CP intake as the level of concentrate mixture increases, the highest being in T4 and the lowest in T1. The CP intake for the different treatments was 3.72, 9.18, 10.71 and 11.97% of total DMI for T1, T2, T3 and T4, respectively. The increased CP intake with the concentrate mixture supplementation level might be due to the increased total DMI and higher CP content of the concentrate mixture than the basal diet, WS. The CP intake of the experiment was comparable with Tesfay (2007) who reported on Afar rams fed on teff straw basal diet supplemented with concentrate mixtures, but lower than the CP intake reported by Bonsi *et al*. (1996) with sheep on teff straw basal diet supplemented with cotton seed cake.

Table 2: Daily feed intake and nutrients of Tigray Highland rams fed on basal diet of Wheat straw and supplemented with graded levels of concentrate mixture

Parameters	control	Amount of concentrate mixture offered (g DM/day)				
		150	200	250	SL	SEM
DMI (WS, g)	495.0^a	429.6^b	407.96^c	393.80^d	***	1.61
DMI (Supplement, g)	-	147.74^c	198.57^b	247.72^a	***	0.19
TDMI(g)	495^c	577.29^b	606.5^{ab}	641.52^a	***	1.60
TDMI g/kg0.75	61.18^a	62.2^a	62.5^a	63.06^a	ns	1.04
OMI WS(g)	460^a	399.0^b	379^c	366^d	***	1.50
OMI Supplement(g)	-	135.19^c	181.72^b	226.71^a	***	0.17
Total OMI(g)	460^c	534.19^b	560.72^b	592.71^a	***	1.48
CPI WS(g)	18.41^a	15.98^{ab}	15.17^{bc}	14.65^c	***	0.06
CPI Supplement(g)	0.0	37.06^c	49.82^b	62.15^a	***	0.06
Total CPI(g)	18.41^d	53.04^c	64.99^b	76.80^a	***	0.07
CFI WS(g)	193.0^b	167.53^a	159.10^a	153.56^{ab}	***	0.63

CFI Supplement(g)	-	15.34[ab]	20.63[a]	25.73[a]	***	0.01
TCFI(g)	193.0[b]	182.87[a]	179.73[a]	179.32[a]	***	0.62
ADF	247.0[a]	244.6[a]	244.27[a]	247.34[a]	ns	0.80
ADLI(g)	28.71[b]	32.98[ba]	34.50[a]	36.36[a]	***	0.09

[a, b, c, d] = means within a row not bearing a common superscript letter significantly differ, ns = not significant; DMI= dry matter intake; SEM= standard error of mean; OMI= organic matter intake; CPI= crude protein intake; CF= crud fiber; ADL= acid detergent lignin; SL= significant level.

The average daily crude protein requirement for maintenance of sheep weighing 30kg was stated to be 36g CP (Ranjhan, 1997), this indicates that the supplemented sheep of the present study had crude protein intake more than their maintenance requirement, but the control treatment was below the maintenance requirement As a result loss in body weight was observed at the end of the experiment. From this finding, the CP content of WS alone was below the maintenance requirement of the experimental animals.

The intake of CF were significantly ($p<0.05$) affected due to supplementation. Sheep in the control treatment consumed higher CF (193 g/d) than the supplemented one (T2, T3 and T4). The reason might be due to high content of CF in the WS. The intake of ADF was not significantly affected due to supplementation. Similar results were reported by Asnakew (2005) and Tesfay (2007) for Hararghe highland goats supplemented with concentrate and fed hay basal diet, and Afar rams supplemented with concentrate mixture and fed teff straw basal diet, respectively.

Digestibility trial

Nutrient digestibility

There was a significant difference in DM, OM and CP ($p<0.05$) digestibility among treatments (Table 3). Apparent nutrient digestibility of DM and OM of the basal diet was significantly increased ($p<0.05$) 14.2% of DM due to supplementation. In line with this result Khanal *et al*. (1999) reported that there was 13.3% increment in apparent DM digestibility for sheep supplementing concentrate mixture.

The apparent digestibility of CP among the supplemented treatments was similar, and was increased due to the high total CP intake of the supplemented animals. Preston *et al*. (1984) reported that any increase in protein intake may lead to an increase in the apparent digestibility of crude protein especially if, the intake is marginally sufficient in protein. In this study supplementation did not significantly ($p>0.05$) affect the CF and ADF apparent digestibility.

Table 3: Apparent Nutrient Digestibility in Tigray highland sheep fed on WS based diet and supplemented with graded levels of concentrate mixture.

	Amount of concentrate mixture offered (g DM/day)					
Nutrients	control	*150*	*200*	*250*	*SL*	*SEM*
DM	61.63^{b}	76.60^{a}	77.67^{a}	79.67^{a}	***	0.23
OM	64.23^{b}	78.65^{a}	79.52^{a}	81.11^{a}	***	0.28
CP	49.55^{b}	74.11^{a}	76.20^{a}	78.24^{a}	***	1.16
CF	54.9^{a}	55.7^{a}	57.81^{a}	60.60^{a}	ns	0.42
ADF	51.01^{a}	53.84^{a}	55.65^{a}	57.15^{a}	ns	0.45

$^{a,\ b}$ = means within a row not bearing a common superscript letter differ significantly; ns= not significant; SEM = standard error of mean; SL= significant level; DM= dry matter; OM= organic matter; CP= crude protein; CF= crude fiber; ADF= acid detergent fiber; T1= treatment one (control); T2 = WS + 150 g concentrate mix; T3 = WS + 200 g concentrate mix; T4 = WS +250 g concentrate mix.

The lower DM, OM, and CP digestibility resulted for the control group could be due to the relatively lower crude protein and higher crude fiber contents of the basal diet. This can affect the microbial growth and fermentation in the rumen of sheep (Bonsi *et al*., 1996). As a result, fiber degradation was lower in the control treatment group, while the opposite could have been true for the supplemented treatments (Ibrahim et al., 1989).

Nitrogen balance

The intake, excretion and retention of N in animals supplemented with the different treatment feeds are shown in Table 5. There were treatment differences in fecal ($P<0.05$), urinary ($P<0.001$) and total ($P<0.001$) N excretion. Nitrogen intake was significantly higher ($P<0.001$) 10.94 g/d and 12.69 g/d in animals supplemented with the 200 and 250 g level of cotton seed cake and wheat bran mixtures respectively. Nitrogen retention was significantly higher ($P<0.001$) 5.69 g/d sheep fed on the 250 g level of cotton seed cake and wheat bran mixtures compared with 3.98 g/d sheep fed on the 150 g level of cotton seed cake and wheat bran mixtures. Moreover, N intake and retention were significantly higher ($P<0.001$) in supplemented with cotton seed and wheat bran mixture compared to the non - supplemented ones.

The use of WS as a sole diet resulted in negative N balance. Previous study also indicated similar negative N balance when *Hyperrhenia rufa* was fed to sheep and goat without supplementation. This could be due to the low N content and poor digestibility of N in WS. Previous studies (Chowdhury, 2002) also indicated similar negative N balance when cereal crop residues of low N content were fed without supplementation.

Table 4: Nitrogen intake, excretion and retention in fed on WS and supplemented with different levels of cotton seed cake and wheat bran mixture.

	Amount of concentrate mixture offered (g DM/day)					
Variables (g/day)	control	150	200	250	SL	SEM
TNI	4.17 ^{b}	9.16 ^{ab}	10.94 ^{a}	12.69 ^{a}	**	0.05
UNE	3.18 ^{b}	3.90 ^{ab}	4.0 ^{ab}	4.20 ^{a}	*	0.03
FNE	1.14 ^{c}	1.28 ^{c}	1.41 ^{b}	2.80 ^{a}	**	0.02
TNE	4.32 ^{d}	5.18 ^{c}	5.41 ^{b}	7.0 ^{a}	*	0.03
NR	-0.15 ^{c}	3.98 ^{b}	5.49 ^{ab}	5.69 ^{a}	**	0.07

Means with different superscripts (a, b, c) in a row are different (*) P<0.05: (**) p<0.001: TNI: total nitrogen intake, UNE: urinary nitrogen excretion, FNE: fecal nitrogen excretion, TNE: total nitrogen excretion, NR: Nitrogen retention, SL significance level, S.E.M standard error of mean.

Positive N balance observed in this study indicates the positive influence of the different treatment supplements in WS based feeding of tigray high land sheep. However, the differences in the quantity and routes of N excretion with level of supplementation had an influence on N metabolism.

Urinary N excretion was lower (P<0.001) in non-supplemented sheep compared to those supplemented with cotton seed cake and wheat bran mixtures. Similarly, lower level of concentrate mixture supplemented exhibited relatively lower urinary excretion (P<0.001) than those supplemented with the highest level of the supplement received. Similar result was found by Solomon (1992) in sheep fed maize Stover supplemented with different type of oil seed cakes such as peanut, sunflower and sesame.

Carcass parameters

Hot carcass weight, dressing percentage and empty body weight

The smallest hot carcass weight (4.66 kg) was recorded for animals on the control treatment, where as the highest hot carcass weight (8.6 kg) was recorded for animals on the highest level of supplementation. The average values of the slaughter weight (SW) and empty body weight (EBW) were significantly (p<0.05) higher for sheep supplemented with 250 g concentrate mixture as compared to sheep supplemented with 150 and 200 g concentrate mixture (Table 5). Hot carcass weight (HCW), and dressing percentage (DP) on slaughter body weight base were also significantly (p<0.05) higher for sheep supplemented with 250 and 200 g as compared to sheep supplemented with 150 g and sheep in the control treatment respectively. Sandros (1993) reported that grazing lambs supplemented with concentrate had significantly higher slaughter weight, hot carcass weight, and dressing percentage than the non-supplemented lambs. Sheep in the control treatment had smaller rib-eye muscle area compared to those supplemented with concentrate mixture. Saikia et al. (1996) reported that rib-eye muscle area was not affected in male goats supplemented with low, medium and high energy feeds. Bhuyan *et al.* (1996) and Shahjalal *et al*. (2000) observed that lower and higher protein supplement to goats had no effect on the rib-eye muscle area. Also Zinn *et al.* (1997) reported that different levels of CSM supplementation to cattle did not affect rib-eye muscle area. Rib-eye muscle area is mostly used as a tool to indicate the proportion of carcass lean meat or an expression of carcass desirability (Wolf *et al*., 1980).

Table 5: Carcass characteristics of highland lambs fed on WS supplemented with graded levels of concentrate mixture.

	Amount of concentrate mixture offered (g DM/day)					
Variables	control	150	200	250	SL	SEM
Slaughter weight (kg)	16.23[b]	18.43[b]	21.00[ab]	23.06[a]	**	0.24
Empty body weight (kg)	10.26[b]	14.30[b]	16.60[ab]	18.20[a]	***	0.15
Hot carcass weight (kg)	4.66[c]	6.92[bc]	7.83[ab]	8.60[a]	***	0.13
Dressing percentage on						
Slaughter weight base	28.73[b]	37.28[a]	37.39[a]	37.55[a]	**	1.13
Empty body weight base	45..50[a]	47.19[a]	47.24[a]	48.40[a]	ns	1.40
Rib-eye area (cm^2)	5.00[b]	6.31[ab]	7.93[a]	8.73[a]	***	0.08

[a, b] = means within a row not bearing a common superscript letter differ significantly; ns= not significant; SEM = standard error of mean; SL= significant level;

The dressing percentage of Tigray highland lambs on the basis of slaughter body weight in the current study were 28.73%, 37.28%, 37.39%, and 37.55% for the lambs fed on the control diet, supplemented with 150, 200, and 250 g concentrate mixtures, respectively. These values on the basis of empty body weight were 45.5%, 47.19%, 47.24%, and 48.40%, respectively. The control group were significantly lower ($p<0.05$) dressing percentage on slaughter weight base than the supplemented treatments, but there was no significant ($p>0.05$) difference between the supplemented treatments. In agreement with this study, Asnakew (2005) indicated that heavier empty body weight for the supplemented group than the control and significant difference between the supplemented groups were observed. Payne and Wilson (1999) also reported that dressing percentage increases with increasing the proportions of concentrate in the ration. According to Devendra and Burns (1983), dressing percentage is described as the proportion of carcass weight to body weight and it assists in assessing the meat proportion of the animals subjectively.

The findings were almost comparable to the results reported by Zemicael (2007) for Arado sheep. Dressing percentage values on empty body weight basis were higher than on slaughter weight basis, implying the influence of digesta (gut fill) on dressing percentage. Ingesta constitutes a large portion of the body weight even when the animals are fasted for long hours, Gibbs and Ivings (1993).Then from this point of view it is more meaningful to express dressing percentage as the proportion of empty body weight than slaughter weight base. Similarly, El-khidir *et. al*. (1998), reported that gut contents contribute 4 - 14% of fasted live weight in sheep and goats fasted for about 24 hours before slaughter. Dressing percentage of sheep are generally between 40 -50%, although affected by different factors. It increases with age, low in young sheep, where there is little muscle and higher in older sheep.

4.5.2 Rib–Eye muscle area

The rib-eye muscle area in the present study was 5.00, 6.31, 7.93, and 8.73cm^2 for control and 150, 200, and 250 g supplemented sheep respectively. Comparable results to this study was reported by Asnakew (2005), from 5.2 to 8.8cm^2 for Hararghe goats, but lower than Mulu (2005), reported 13, 13.5, and 19.5cm^2 for Wegera sheep. In the current study, there was a significantly higher ($p<0.05$) rib-eye area for the high level concentrate mixture supplemented lambs (250g/d) than the control one, but there was no significant difference ($p>0.05$) between the control and the 150 g/d supplemented group; and among the supplemented treatments (150, 200 and 250 g/d).

However, lambs in the highest level of supplementation (250 g/d) exhibited higher (8.8cm^2) rib-eye area than the other treatment feeds. This was an implication of lambs supplemented with different levels of concentrate mixture were able to accommodate relatively better lean flesh than lambs fed wheat straw alone. This finding was inline with many other studies, (Asnakew, 2005; Mulu, 2005; Simret, 2005; and Zemicael, 2007).

4.5.3 Edible and Non-edible offals of the carcass

Lung, trachea & esophagus, heart, liver with gallbladder, empty gut (reticulo-rumen + omaso-abomasum + small intestine + large intestine), visceral fat (kidney fat + omental fat), tail, head with tongue, and kidneys are considered as edible offals. Where as blood, spleen and pancreas, skin and feet, testicles and penis and gut contents are considered as non-edible offals. Based on the eating habit of the study area.

Table 6: Edible carcass offals of Tigray highland sheep fed on WS based diet and supplemented with graded levels of concentrate mixtures.

	Amount of concentrate mixture offered (g DM/day)					
Parameters	control	150	200	250	SL	SEM
Lung,trach and esoph (Kg)	0.33^a	0.34^a	0.34^a	0.37^a	ns	0.01
Heart (kg)	0.071^b	0.079^b	0.081^a	0.086^a	**	0.001
Liver & gallbladder (Kg)	0.21^b	0.36^a	0.34^a	0.336^a	**	0.005
Empty gut (Kg)	1.30^a	1.51^a	1.513^a	1.49^a	ns	0.009
Total fat (Kg)	0.07^b	0.13^{ab}	0.18^a	0.21^a	***	0.002
Tail (Kg)	0.28^c	0.54^{bc}	0.58^{ab}	0.79^a	***	0.007
Head and Tongue (Kg)	1.40^a	1.41^a	1.43^a	1.46^a	ns	0.009

$^{a, b, c,}$ means the same row with different superscripts differ significantly; ns = not significant; TEOC= total edible offal component; SL= significant level; SEM= Standard error of mean.

In the current study, the size of heart, liver with gallbladder, total fat, tail, kidney and total edible offal component were significantly ($p<0.05$) affected by supplementation (Table 6). Kirton *et al*. (1992) reported that live weight and nutritional status of the animals can affect the production efficiency of carcass offals. The total edible offal components (TEOC) were significantly lower ($p<0.05$) 3.84 kg in the control treatment compared to the highest level of concentrate mixture supplemented treatment (250 g/d). However, there was no significant difference ($p>0.05$) on the combined weight of lung, trachea, and esophagus; head with tongue and empty gut due to supplementation.

Sheep supplemented with concentrate mixture had significant ($p<0.05$) difference in visceral fat, and tail than the control treatments. This fat deposit could be attributed to the fact that supplemented sheep tend to deposit more fat in their body as compared to the non-supplemented ones. Galal *et al.* (1997b) indicated that there was heavier fat as indicated by visceral fat and tail weight for grazing adult lambs supplemented with concentrate feeds. On the other hand, animals fed low quality feed use their fat body reserve in order to fulfill their nutrient requirement that leads to decreased fat storage in their body and as a result mobilization of body fat reserves will start. This is pronounced during dry season and prolonged underfeeding Kirton *et al*. (1992).

Table 7: Non-edible carcass offals of Tigray highland sheep fed on WS based diet and supplemented with graded levels of concentrate mixtures.

Parameters	control	Amount of concentrate mixture offered (g DM/day)				
		150	200	250	SL	SEM
Blood (Kg)	0.55^{b}	0.75^{ab}	0.78^{ab}	0.83^{a}	**	0.008
Spleen and pancreas (Kg)	0.036^{b}	0.047^{ab}	0.055^{a}	0.058^{a}	**	0.005
Skin and feet (Kg)	1.87^{b}	2.31^{ab}	2.48^{a}	2.57^{a}	*	0.01
Testicle and penis (Kg)	0.14^{a}	0.22^{ab}	0.24^{ab}	0.29^{a}	*	0.003
Gut Content (Kg)	4.25^{a}	4.15^{a}	3.77^{a}	3.35^{a}	ns	0.08
TNEOC (Kg)	7.62^{a}	7.45^{a}	7.29^{a}	7.10	ns	0.07
TNEOC %	46^{a}	40^{b}	34^{c}	30^{c}	**	0.61
TUp	8.51^{c}	11.53^{bc}	12.47^{ab}	13.54^{a}	*	0.13
TUP %	52.44^{c}	58.7^{b}	59.51^{ab}	62.59^{a}	***	1.52

$^{a, b, c}$ means the same row with different superscripts differ significantly; ns = not significant; TEOC= total edible offal component; TNEOC= total non-edible offal component; TUP= total usable product; SL= significant level; SEM= Standard error of mean.

There was a significant difference ($p<0.05$) due to supplementation on blood, spleen and pancreas, skin and feet and TNEOC%. Prasad V.S.S and A.H. Kirton, (1992) reported that live weight and nutritional status of the animals can affect the production efficiency of carcass offals. In most of the total edible offal components (TEOC) were significantly lower ($p<0.05$) in the control treatment compared to the highest level of concentrate mixture supplemented. But there were no significant difference ($p>0.05$) on gut content and total non-edible offal component (TNEOC) (Kg) from the non-edible offals.

The decreasing trend of gut content with increasing concentrate mixture level might be contributed to the expected higher rate of digestion and faster passage rate of the diet through the digestive tract due to consumption of more digestible feed. However animals on poor feed are forced to fill their gut with less digestible roughage and have proportionally bigger gut content. This result was also in agreement with the views of Vansoest (1994) and Pond *et al*. (1995).

The total usable product were also significantly lower ($p<0.05$) for the control and 150 g/d concentrate mixture supplemented treatments as compared to 250 g/d supplemented treatment. The significant difference observed in the total usable product was mainly due to the higher value of dressing percentage which is affected by level of nutrition among the other factors. The weight of skin of lambs supplemented with the highest concentrate mixture were significantly higher ($p<0.05$) than lambs kept only on wheat straw. The increasing trend of the external offals (skin) might be due to an increase in subcutaneous fat deposition in the skin (Lawrence and Fowler, 1997). Similar results were also reported by Mulu (2005) on wogera sheep fed hay and supplemented with brewery dried grain.

Correlation between slaughter weight carcass, dressing percentage based on empty body weight, rib-eye area and offal components

The correlation analysis revealed that slaughter weight was positively and significantly ($p<0.05$) correlated with empty body weight, hot carcass weight, rib eye area; liver, heart, kidney and dressing percentage (DP) as slaughter weight base. In contrary to the present result, Sendros *et al*. (1993) in their carcass characteristics study on local Menz sheep and their crosses, kept under different feeding regimen, found negative but insignificant relationship between slaughter weight and rib-eye muscle area. But Asnakew (2005) reported positive and significant correlation among SW, EBW, DP and HCW. Similarly, Galal *et al*. (1997a) observed positive correlation between SW, HCW, and DP. In the current study for Tigray highland sheep, which were inline with the present results. On the other hand SW, EBW, HCW, liver, heart and REA exhibited insignificant ($p>0.05$) and negative relationship with VF (visceral fat).But, there was also negative and significant ($p<0.05$) relationship of gut content with HCW, REA, kidneys; SW, EBW, VF and heart.

Table 8: Correlation between carcass parameters of Tigray highland rams fed on WS supplemented with graded levels of concentrate mixture

	SW	EBW	HCW	DP	REA	Heart	Liver	VF	Kidney	GC
SW	1									
EBW	0.96***	1								
HCW	0.93***	0.98***	1							
DP	0.69**	0.83*	0.89*	1						
REA	0.97**	0.98**	0.97***	0.80ns	1					
Heart	0.94**	0.85**	0.81**	0.49*	0.88***	1				
Liver	0.75***	0.85***	0.89***	0.93*	0.81*	0.54**	1			
VF	- 0.68^{ns}	-0.81^{ns}	-0.83^{ns}	-0.89^{ns}	-0.74^{ns}	-0.43^{ns}	-0.94^{ns}	1		
Kidney	0.92*	0.96^{ns}	0.96*	0.85^{ns}	0.95^{ns}	0.78^{ns}	0.88ns	0.82^{ns}	1	
GC	-0.95*	-0.97*	-0.98**	-0.83^{ns}	-0.98*	-0.85**	-0.86**	-0.76*	-0.94^{ns}	1

ns =non significant; SW = slaughter weight; EBW = empty body weight; HCW = hot carcass weight; DP = dressing percentage; REA = rib-eye –area; VF = visceral fat; Visceral fat include (omental fat + kidney fat); GC= gut contents; WS = wheat straw.

Conclusions

Generally, the present study indicated that supplementation of growing lambs with graded levels of concentrate mixture on WS had improved feed intake, digestibility, and carcass parameters. Moreover, it was concluded that supplementation of 250 g DM concentrate mix resulted in better feed intake, and carcass traits in WS based feeding of growing lambs compared to other supplementations and could be recommended.

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