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# Substitution of dried mulberry (*Morus indica* L.) leaf meal for concentrate mix on feed intake, digestibility, body weight gain and carcass characteristics of Abergelle sheep

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**The study was conducted at Abergelle Agricultural Research Center, Ethiopia using 24 yearling intact male Abergelle sheep with initial body weight of 17.52 ± 1.13 kg. The objectives were to evaluate substitution of dried mulberry (Morus indica L.) leaf meal (DMLM) for concentrate mix (CM) on feed intake, digestibility, body weight gain and carcass characteristics, and to determine cost benefit analysis of the supplementary regimes. The study comprised 90 days of feeding trial, 7 days of digestibility trial and carcass evaluation at the end. Six sheep were randomly assigned to each treatment using randomized complete block design. The treatments included feeding of ad libitum natural grass hay and supplementation with 100% CM (T1); 75% CM + 25% DMLM (T2); 50% CM + 50% DMLM (T3) and 25% CM + 75% DMLM (T4) on DM basis. The supplements were prepared iso-nitrogenous and they were offered to meet daily CP requirements of 80.4, 95.7 and 108 g for rams with body weight of 15, 20 and 25 kg, respectively. At beginning of experiment, amount of supplements provided were 439.49, 440.51, 440.75 and 440.50 g on DM basis for T1, T2, T3 and T4, respectively. The CM contained noug seed cake (NSC) and wheat bran (WB) at ratio of 19.28: 80.72, 14.14: 60.86, 9.04: 40.96 and 3.92: 21.08 for T1, T2, T3 and T4, respectively. The CP content of grass hay, WB, NSC and DMLM were 7.20, 16.80, 33.40 and 20.20%, respectively. The OM, CP, NDF, ADF and ADL intakes and digestibilities were similar among treatments but, hay and total DM intakes as well as DM digestibility were significantly higher (p<0.05) in T3 than T1. Calculated ME was greater (p<0.01) in T3 and T2 than T4 but similar in T1, T2 and T3. There was no significant differences among treatments for feed conversion efficiency, final body weight, ADG and most carcass parameters measured. The partial budget analysis showed that T4 had highest economical gain. Therefore, T4 is recommended on both biologically and economically efficient supplementary regime for Abergelle sheep.**

**Key words:** Economical gain, feed conversion efficiency, isonitrogenous, noug seed cake, wheat bran.

## INTRODUCTION

There are about 1.82 and 29.33 million sheep in Tigray region and Ethiopia, respectively (CSA, 2015). Indigenous sheep in Ethiopia have a multipurpose role for smallholder farmers like sources of income, meat, skin, manure and coarse wool (Markos, 2006; Mengesha and Tsega, 2012; Gizaw et al., 2013).

As reported by FAO (2013) sheep meat consumption trends in Ethiopia grow from 36000 ton in 2000 to 86000 ton in 2012. Sheep accounted 34% of the live animal exports (Gizaw et al., 2013). Moreover, sheep together with goats contributed 86% of the total value of meat exports (Legese and Fadiga, 2014). Even though the sheep population provided considerable roles to both smallholder farmers and the country's economy but their present contribution is far below their potential. This is because productivity of sheep is hampered by many factors. However, Yami (2008) indicated that the nutrition of sheep and goats is the most important factor affecting their performance. Similarly, Gizaw et al. (2010) and Tesfay et al. (2012) noted that small ruminants usually suffer from feed shortage and poor nutrition. The common feeds in Ethiopia such as crop residues and matured natural pasture are inherently low in crude protein (CP), minerals and digestibility (Tolera, 2008; Gizaw et al., 2010).

One way of improving the poor quality of the feed resources is by supplementation with other high quality feeds. Concentrate feeds (agro-industrial by products) have a good potential of supplementation value but in most developing countries like Ethiopia concentrates are expensive, are in short supply and may not be easily accessible to smallholder farmers (Tolera et al., 2000). Hence, there is a need to search for supplement sources that could be applied at smallholder farmer levels with affordable costs. The use of leaves' of some trees and shrubs like leaf of mulberry plant as substitution to concentrate supplementation may be one of the alternative solutions. It has been noted that the nutritive value of mulberry plants is one of the highest found in products of vegetable origin and of far superior to traditional forages like alfalfa (Benavides, 2000; Doran et al., 2007).

Though the availability has not been well quantified, large numbers of mulberry trees are present in different areas of Ethiopia particularly in Tigray region. However, in most of the areas, their leaves remained unused due to non-availability of silkworm rearing. Therefore, the objectives of the study were to evaluate substitution of dried mulberry (*Morus indica* L.) leaf meal (DMLM) for concentrate mix (CM) on feed intake, digestibility, body weight gain and carcass characteristics of Abergelle sheep as well as to determine cost benefit analysis of the supplementary regimes.

## MATERIALS AND METHODS

### Study site

The study was conducted at Abergelle Agricultural Research Center in Tanqua Abergelle district, Ethiopia. It is located at 13°14'06"N latitude and 38°58'50"E longitude. The district is categorized as hot to warm sub-moist lowland (SM1-4) sub-agro ecological zone of Tigray region with an altitude of 1300 - 1800 masl. Its mean annual rainfall ranges from 400 - 650 mm and the mean annual temperature ranges from 21 to 41°C.

### Feed preparation and feeding

Natural grass hay was harvested from Abyi-Adi skill development and training center in Kola Tembien district while the mulberry leaves were collected from both farmers and forage nursery site in Tanqua Abergelle district during September. The mulberry leaves were harvested manually with leaf picking method and immediately, they were spread thinly on plastic sheet under shed in well-ventilated room for drying with turning of 10 - 12 times/day. Finally, they were milled using mortar and pestle to make in form of meal. Wheat bran (WB) and noug seed cake (NSC) were purchased from market in Mekelle city. The natural grass hay was offered ad libitum (about 20% refusal on DM basis) and the supplements were given twice daily in equal quantities at 8.00 am and 4.00 pm to each experimental ram.

### Experimental animals' management

Twenty four yearling intact Abergelle rams were selected randomly and purchased from market at Yechila town in Tanqua Abergelle district, Ethiopia. The rams were ear tagged for identification. They were treated against internal and external parasites with Albendozole and Vetazinon 60% EC, respectively as per the recommended dosage. They were also vaccinated against ovine pasturelosis which is the most common disease in the area, and housed in individual pens equipped with feeding and watering troughs. The rams were adapted to experimental feeds for 15 days and then followed by 90 days of feeding trial. Besides, each experimental ram had free access to salt block and fresh water daily.

### Experimental design and treatments

The experiment was conducted using a randomized complete block design (RCBD) with 4 treatments and 6 replications. Initial body weight of the rams was applied as block and experimental rams were randomly assigned to the dietary treatments within the block. The initial body weight of experimental rams was 17.52 ± 1.13 kg (mean ± SD) while the average initial body weights of the rams in each group were 17.50, 17.52, 17.53 and 17.52 kg for T1, T2, T3 and T4, respectively. The supplements were prepared isonitrogenous having almost the same 20% CP and they were offered according to recommendation of Ranjhan (2004) to meet daily CP requirements of 80.4 g, 95.7 g and 108 g for growing lambs with body weight of 15, 20 and 25 kg, respectively to get daily gain of 100 - 120 g. The dietary treatments included feeding of ad libitum natural grass hay and supplementation with 100% CM (T1); 75% CM + 25% DMLM (T2); 50% CM + 50% DMLM (T3) and 25% CM + 75% DMLM (T4) on DM basis. The CM was formulated using NSC and WB at ratio of 19.28: 80.72, 14.14: 60.86, 9.04: 40.96 and 3.92: 21.08 for T1, T2, T3 and T4, respectively. At the beginning of the study, CP requirements of the experimental

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rams were 87.90, 88.10, 88.15 and 88.10 g while the amounts of supplements provided to meet the aforementioned CP requirements were 439.49, 440.51, 440.75 and 440.50 g on DM basis for T1, T2, T3 and T4, respectively and they were changed fortnightly according to the change in body weight.

**Feed intake and body weight measurements**

The amounts of feed offers and refusals for each ram were recorded every day throughout the experimental period. The DM intake was calculated as difference between amounts of feed offered and amounts of feed refusals on DM basis. Similarly, nutrient intake was computed as difference between nutrient content of feed offered and nutrient content in feed refusals. The body weight measurement was taken fortnightly for each ram for the whole experimental period after overnight fasting. The initial body weight of experimental rams was measured at the end of adaptation period while final body weight was measured at the end of feeding trial (growth period). The average daily gain (ADG) was calculated by subtracting initial body weight from final body weight and then after dividing it to the number of feeding days. Feed conversion efficiency was determined as ratio of ADG to daily DM intake.

**Digestibility trial**

Digestibility trial was conducted following the feeding trial. The total wet feces for each ram were measured for 7 consecutive days after 3 days of adaptation of the rams for carrying of the fecal bags. The daily fecal excretion of each ram was mixed thoroughly and 10% was sampled and kept in airtight plastic bags and stored at -20 $^{o}$C refrigerator. At the end of the fecal collection period the fecal samples were pooled per treatments and 20% were sub-sampled to determine chemical composition. The apparent digestibility coefficient of DM and nutrients were calculated as follows;

$$\text{Apparent DM digestibility coefficient} = \frac{\text{Total DM intake} - \text{DM in feces}}{\text{Total DM intake}}$$

$$\text{Apparent nutrient digestibility coefficient} = \frac{\text{Total nutrient intake} - \text{Nutrient in feces}}{\text{Total nutrient intake}}$$

The percent (%) total digestible nutrients (TDN) for each dietary treatment was computed by summing % digestible CP, % digestible crude fiber (CF), % digestible nitrogen free extract (NFE) and % digestible ether extract (EE) multiplied by a factor of 2.25. The TDN value of the dietary treatments was used to derive metabolizable energy (ME) using the relation of 1 kg TDN is equal to 3616 Kcal ME.

**Carcass evaluation**

At the end of digestibility trial, all experimental rams were taken to Abergelle International Export Abattoir and slaughtered after overnight fasting for evaluation of carcass parameters using a standard slaughtering method. Slaughter weight (SW) was taken immediately before slaughter. Hot carcass weight was measured after removal of blood, skin, head, feet (legs below the hock and knee joints), gastrointestinal tract and internal organs. Liver, bile without gallbladder, heart, heart fat, reticulo-rumen, abomasum-omasum, testicles, kidney, omental and kidney fats, tongue, tail, small and large intestines were weighed, and recorded as total edible offals while blood, head without tongue, skin with feet, lungs, trachea and esophagus, penis, gallbladder without bile, spleen, pancreases and gut content were weighed, and recorded as total non-edible offals. Empty body weight was calculated as the difference between SW and gut content. Dressing percentage was determined as proportion of hot carcass weight to SW.

The ribeye area is determined by measuring area of the *Longissimus dorsi* muscle exposed by cutting or "ribbing" the carcass between the 12$^{th}$ and 13$^{th}$ ribs (O'Rourke et al., 2004). The backfat which is the most common measure of subcutaneous fat on a carcass is measured at a point ¾ of length of ribeye (L*ongissmus dorsi*) muscle from the split chine bone, perpendicular to the surface fat, at the 12$^{th}$ rib (Williams, 2002).

**Chemical analysis**

Chemical analysis of representative samples of feed (hay and supplements) offer, hay refusals, and feces for dry matter (DM), Ash, crude fiber (CF) , ether extract (EE) and nitrogen (N) content were analyzed using the procedures outlined by AOAC (2005). The N content was determined by Kjeldahl method and then the CP was calculated by N content multiplied by 6.25. The organic matter (OM) was calculated by subtracting total ash content from DM content of a feed sample while NFE was computed by subtracting sum of CP, CF, EE and total ash contents from DM content of a feed sample. Neutral detergent fiber (NDFom), acid detergent fiber (ADFom) and acid detergent lignin (ADL) of the samples were analyzed according to method of Van Soest et al. (1991). Sulfite and Alpha-amylase were not applied as reagents in the analysis of NDFom. Pre - experiment analysis for DM and CP contents of DMLM, WB and NSC were done at Mekelle soil laboratory research center and the remaining all other parameters were analyzed at Haramaya University Animal nutrition laboratory.

**Partial budget analysis**

The partial budget analysis was performed to determine cost benefit analysis of substitution of DMLM for CM as supplement to Abergelle sheep fed a basal diet grass hay. At the end of experiment, selling prices of each experimental ram were estimated. Variable costs included feed costs for both hay and supplement consumed. Total return (TR) was determined by subtracting purchasing prices of experimental rams from their estimated selling prices. Net return (NR) was calculated as the difference between TR and total variable costs (TVC) while change in net return (ΔNR) was calculated as difference between change in total return (ΔTR) and change in total variable costs (ΔTVC).

**Statistical analysis**

The data obtained from the experiment were subjected to analysis of variance (ANOVA) using the general linear model procedure of SAS version 9.2 (SAS, 2008). Significant treatment means were compared using Tukey's studentized range (HSD) test. The statistical model used for the data analysis was:

$$Y_{ij} = \mu + \tau_i + \beta_j + \varepsilon_{ij},$$

where $Y_{ij}$ = response variable; μ = overall mean; τi = effect of treatment i;
$\beta_j$ = effect of block j and εij = random error.

## RESULTS AND DISCUSSION

### Chemical composition of experimental feeds

The hay refusals had lower CP and relatively higher NDF,

**Table 1.** Chemical composition of experimental feeds and hay refusals.

| Experimental feeds | DM (g/kg) | Chemical composition DM (g/kg) | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | CP | Ash | NDF | ADF | ADL | CF | EE |
| Dried mulberry leaf | 943.0 | 202.0 | 120.6 | 329.7 | 230.6 | 44.0 | 118.6 | 40.2 |
| Wheat bran | 924.0 | 168.0 | 63.0 | 483.1 | 143.2 | 34.0 | 121.1 | 44.1 |
| Noug seed cake | 945.0 | 334.0 | 82.9 | 365.4 | 262.0 | 104.0 | 181.7 | 88.7 |
| Grass hay offers | 945.7 | 72.0 | 84.4 | 748.6 | 509.8 | 113.6 | 385.5 | 14.0 |
| 100% CM | 928.0 | 200.3 | 66.8 | 410.4 | 176.0 | 47.5 | 132.8 | 52.7 |
| 75% CM + 25% DMLM | 931.7 | 200.1 | 80.2 | 388.1 | 169.8 | 46.4 | 129.0 | 49.4 |
| 50% CM + 50% DMLM | 935.4 | 200.4 | 93.6 | 365.7 | 170.1 | 44.8 | 125.3 | 46.2 |
| 25% CM + 75% DMLM | 939.1 | 200.0 | 107.0 | 353.4 | 174.0 | 44.2 | 121.6 | 42.9 |
| Grass hay refusals | 946.1 | 49.7 | 63.2 | 767.7 | 536.3 | 128.9 | 435.0 | 12.2 |

CM = concentrate mix (the CM contained noug seed cake and wheat bran at ratio of 19.28: 80.72, 14.14: 60.86, 9.04: 40.96 and 3.92: 21.08 for 100% CM, 75% CM, 50% CM and 25% CM, respectively); DMLM = dried mulberry leaf meal; DM = dry matter; CP = crude protein; NDF = neutral detergent fiber; ADF = acid detergent fiber; ADL= acid detergent lignin; CF = crude fiber and EE = ether extract.

ADF and ADL contents than hay offers (Table 1). The CP content of grass hay in the present study was similar to the CP value of 73 g/kg DM reported by Gebru (2015) for native hay. Moreover, it was very close to border-line level of 60- 70 g/kg DM CP required to create an appropriate rumen environment to promote DM digestibility and intake (Yami, 2008). The CP content of DMLM in this study was comparable with previously reported values of 201 g/kg DM (Kandylis et al., 2009) and 203 g/kg DM (Vu et al., 2011). The CP content of WB in the present study was similar with values of 168 g/kg DM (Tolera, 2008) and 168.2 g/kg DM (Hagos and Melaku, 2009). The CP content of NSC in the present study was comparable to value of 331 g/kg DM noted in earlier study (Abraham et al., 2015). Tolera (2008) indicated that CP and fat content of NSC varies depending upon the method and efficiency of oil extraction from the noug seeds.

The NDF and ADF contents of the grass hay in the present study were within the ranges of 731 – 772.5 and 429.9 – 537.6 g/kg DM, respectively reported by Tesfay et al. (2009) for different grass species when harvested at mid-September. The grass hay nutritive value declined with advanced stage of harvesting and in general grasses should be harvested for hay making immediately before or at the beginning of flowering (Tolera, 2008). The NDF content of DMLM was similar to value of 324 g/kg DM reported by Vu et al. (2011) while its ADF content was within the range of 186.7 – 246.7 g/kg DM reported by Kabi and Bareeba (2008) for mulberry leaves. The ADL of DMLM in the present study was nearly similar with previous findings of 41 g/kg DM (Kandylis et al., 2009) and 46.5 g/kg DM (Atiso et al., 2012). As reported by Sanchez (2000) the chemical composition of mulberry leaves varies depending on variety, harvesting stage and growing conditions. Comparable to the NDF content of WB in the present study, values of 484 g/kg DM by Gebeyew et al. (2015) and 480.1 g/kg DM by Gebru et al. (2015) were documented. The ADF content of WB in this study was greater than the value of 105 g/kg DM reported in earlier study (Megersa et al., 2013). It has been noted that fiber content of WB may vary depending upon the quality of wheat being milled and the exact processing method used (Tolera, 2008). In consistent with the NDF content of NSC in this study, values of 365 g/kg DM by Kebede (2014), 363 g/kg DM by Girma et al. (2014) and 367 g/kg DM by Abraham et al. (2015) were reported. Comparable to ADF content of NSC in the present study values of 264 g/kg DM by Asmare et al. (2010) and 261 g/kg DM by Nurfetaa et al. (2013) have been reported.

### Dry matter and nutrient intake

All the quantities of supplements offered to the experimental rams were completely consumed without any refusals. It is observed that offering of dried mulberry leaves as meal form avoided selection intakes of the leaves and also facilitated quick consumption. There was significance differences ($p<0.05$) for hay and total DM intakes between T1 and T3 (Table 2). The reason for the difference in hay and total DM intakes between T1 and T3 might be due to the higher DM digestibility observed in T3 than T1 because in ruminants there is a positive relationship between the digestibility of feeds and their intake (McDonald et al., 2010). In consistence with the present study, Atiso et al. (2012) reported increasing total DM intake with substitution of 50% of mulberry leaves for concentrate compared to sole CM supplementation in dairy cows. The OM, CP, NDF, ADF and ADL intakes of experimental rams were similar among treatments.

The daily CP intake of Abergelle rams in the present experiment was higher than the CP intakes of sheep in many other studies (Gebru, 2012; Hadgu, 2014; Teklehaymanot, 2015). The higher CP intake of Abergelle rams observed in the present study might be due to the

**Table 2.** Daily dry matter and nutrient intakes of Abergelle rams supplemented with graded levels of dried mulberry leaf meal and concentrate mix.

| Intake (g/day/head) | Treatments | | | | SEM | SL |
|---|---|---|---|---|---|---|
| | T1 | T2 | T3 | T4 | | |
| Hay DM | 449.99[b] | 462.87[ab] | 482.21[a] | 465.90[ab] | 6.90 | * |
| Supplement DM | 469.96 | 476.32 | 479.25 | 478.12 | 4.39 | ns |
| Total DM | 919.95[b] | 939.19[ab] | 961.46[a] | 944.03[ab] | 9.23 | * |
| OM | 847.09 | 858.84 | 873.30 | 850.26 | 8.60 | ns |
| CP | 130.20 | 131.91 | 133.51 | 132.61 | 1.07 | ns |
| NDF | 526.59 | 528.59 | 533.90 | 514.78 | 6.06 | ns |
| ADF | 309.45 | 313.61 | 322.06 | 316.98 | 3.90 | ns |
| ADL | 69.21 | 70.96 | 73.14 | 70.11 | 0.97 | ns |

[abc] = mean in the same row with different superscript differ significantly; * = p<0.05; ns= non-significant; T1 = ad libitum natural grass hay (NGH) + 100% CM; T2 = ad libitum NGH + 75% CM + 25% DMLM; T3 = ad libitum NGH + 50% CM + 50% DMLM; T4 = ad libitum NGH + 25% CM + 75% DMLM; DM = dry matter; OM = organic matter ; CP = crude protein; NDF = neutral detergent fiber; ADF = acid detergent fiber; ADL = acid detergent lignin; SEM = standard error of mean and SL = significance level.

**Table 3.** Apparent dry matter and nutrient digestibility coefficient of graded levels of dried mulberry leaf meal and concentrate mix supplemented for Abergelle rams.

| Digestibility coefficient | Treatments | | | | SEM | SL |
|---|---|---|---|---|---|---|
| | T1 | T2 | T3 | T4 | | |
| DM | 0.693[b] | 0.700[ab] | 0.702[a] | 0.700[ab] | 0.18 | ** |
| OM | 0.70 | 0.70 | 0.71 | 0.71 | 0.18 | ns |
| CP | 0.76 | 0.76 | 0.76 | 0.76 | 0.14 | ns |
| NDF | 0.58 | 0.59 | 0.60 | 0.59 | 0.47 | ns |
| ADF | 0.56 | 0.56 | 0.57 | 0.57 | 0.65 | ns |
| Calculated ME (MJ/day) | 10.95[ab] | 11.00[a] | 11.01[a] | 10.87[b] | 5.35 | ** |

[abc] = mean in the same row with different superscript differ significantly; ** = p<0.01); ns= non-significant; T1 = ad libitum natural grass hay (NGH) + 100% CM (control); T2 = ad libitum NGH + 75% CM + 25% DMLM; T3 = ad libitum NGH + 50% CM + 50% DMLM; T4 = ad libitum NGH + 25% CM + 75% DMLM; DM = dry matter; OM = organic matter; CP = crude protein; NDF = neutral detergent fiber; ADF = acid detergent fiber; ME= metabolizable energy; SEM = standard error of mean and SL = significance level.

amount of supplements were prepared according the daily CP requirement of each ram and they were also changed fortnightly based on the change of body weight, and the high digestibility of CP.

### Apparent dry matter and nutrient digestibility

The DM digestibility coefficient was significantly different (p<0.01) between T1 and T3 with higher value for T3 but similar in T2, T3 and T4 (Table 3). The lower DM digestibility observed in T1 compared to T3 might be associated with the relatively higher NDF content of both WB and NSC, and greater ADL concentration of NSC existed in the supplement of T1 as the fibre fraction of a feed has the greatest influence on its digestibility (McDonald et al., 2010). Moreover, McDonald et al. (2010) also indicated that the digestibility of a feed is influenced by the composition of other feeds consumed with it and the associative effects could be negative or positive. Comparable values to DM digestibility coefficient in the present study have been reported for dried mulberry leaves partially substituted lucerne hay and concentrates in Karagouniko sheep breed by Kandylis et al. (2009) and for graded levels of dried mulberry leaves and concentrate mix in Arsi-Bale goats by Worku (2015).

The OM, CP, NDF and ADF digestibility coefficients were insignificant (p>0.05) among dietary treatments. Similar to OM digestibility coefficient in this study, value of 0.70 for mature indigenous Malin rams supplemented at 1.2% of body weight with mixture of mulberry foliage (50%) and urea-rice bran (50%) has been noted (Yulistiani et al., 2014). In agreement to the present study Worku (2015) reported CP digestibility coefficient of 0.75 – 0.77 for dried mulberry leaves included at different levels in concentrate for Arsi- Bale goats.

**Table 4.** Body weight gain and feed conversion efficiency of Abergelle rams supplemented with graded levels of dried mulberry leaf meal and concentrate mix.

| Parameters | Treatments | | | | SEM | SL |
|---|---|---|---|---|---|---|
| | T1 | T2 | T3 | T4 | | |
| Initial body weight (kg) | 17.50 | 17.52 | 17.53 | 17.52 | 0.171 | ns |
| Final body weight (kg) | 22.98 | 23.70 | 23.9 | 23.75 | 0.476 | ns |
| ADG (g/day) | 60.93 | 68.70 | 70.74 | 69.26 | 5.019 | ns |
| FCE (g weight gain /g DM intake) | 0.066 | 0.073 | 0.074 | 0.073 | 0.005 | ns |

T1 = ad libitum natural grass hay (NGH) + 100% CM; T2 = ad libitum NGH + 75% CM + 25% DMLM; T3 = ad libitum NGH + 50% CM + 50% DMLM; T4 = ad libitum NGH + 25% CM + 75% DMLM; ADG = average daily gain; FCE= Feed conversion efficiency; SEM = standard error of mean; SL = significance level and ns = non-significant.

**Table 5.** Carcass characteristics of Abergelle rams supplemented with graded levels of dried mulberry leaf meal and concentrate mix.

| Parameters | Treatments | | | | SEM | SL |
|---|---|---|---|---|---|---|
| | T1 | T2 | T3 | T4 | | |
| SW (kg) | 22.83 | 23.57 | 23.77 | 23.62 | 0.469 | ns |
| Empty body weight (kg) | 18.78 | 19.35 | 19.47 | 19.30 | 0.397 | ns |
| Hot carcass (kg) | 9.52 | 9.86 | 10.01 | 9.88 | 0.202 | ns |
| Dressing percentage based on SW (%) | $41.70^{b}$ | $41.83^{b}$ | $42.11^{a}$ | $41.85^{b}$ | 0.052 | *** |
| Ribeye area ($cm^2$) | 8.43 | 8.92 | 8.98 | 8.93 | 0.206 | ns |
| Back fat thickness (mm) | 2.82 | 2.87 | 2.92 | 2.88 | 0.075 | ns |
| TEOs (g) | 3032.88 | 3096.68 | 3155.07 | 3100.38 | 45.488 | ns |
| TNEOs (g) | 10004.20 | 10321.83 | 10337.88 | 10333.28 | 224.151 | ns |

$^{ab}$ = mean in the same row with different superscript differ significantly; *** = P<0.0001; ns = non significant; T1 = ad libitum natural grass hay (NGH) + 100% CM; T2 = ad libitum NGH + 75% CM + 25% DMLM; T3 = ad libitum NGH + 50% CM + 50% DMLM; T4 = ad libitum NGH + 25% CM + 75% DMLM; SW = Slaughter weight; TEOs = total edible offal's; TNEOs = total non-edible offal's; SEM = standard error of mean and SL = significance level.

The calculated ME were lower (p<0.01) in T4 than T2 and T3 but similar in T1, T2 and T3. Ranjhan (2004) recommended that 0.35 kg TDN for daily maintenance requirement of Indian sheep of 30 kg body weight as well as 0.32, 0.40 and 0.51 kg TDN for daily growth requirement of Indian lambs of 15, 20 and 25 kg body weight, respectively. According to recommendation of the above author both maintenance and growth ME requirements for T1, T2, T3 and T4 are 9.10, 9.26, 9.31 and 9.29 MJ, respectively. However, the actually used ME of Abergelle rams in the present study exhibited an increment of 20.32, 18.79, 18.25 and 17.09% compared to the expected total ME requirements of maintenance and growth for T1, T2, T3 and T4, respectively and this difference might be due to variations in breed, environment and other factors.

## Body weight gain and feed conversion efficiency

There was no significant difference among treatments for final body weight, ADG and FCE (Table 4). Similar to the present study, insignificant results for final body weight, ADG and FCE were reported by Worku (2015) for Arsi-bale goats when supplemented with inclusion of graded levels of dried mulberry leaf in CM consisted of WB and NSC. The ADG of Abergelle rams in the present experiment was higher than ADG of 55 g reported by Liu et al. (2001) for growing sheep of the Huzhou breed supplemented with 240 g air dried mulberry leaves but lower than ADG of 76.2 g and 86.2 g (Gonzalez and Milera, 2000); 121 g (Miller et al., 2005) and between 80 g and 90 g (Martin et al., 2014) were reported in previous studies for goat breeds supplemented with mulberry leaves. The FCE of Abergelle rams obtained in the present study was similar to previously reported values for Tigray highland sheep with supplementation of 200 g WB and 400 g air dried *Acacia saligna* leaves (Gebru, 2012) and with supplementation of 306 g sole WB (Berihe et al., 2014).

## Carcass characteristics

There was no significant difference (p>0.05) among treatments for SW, empty body weight, hot carcass, ribeye area, backfat thickness, total edible offal's and total non-edible offal's but T3 had significantly higher (p<0.001) dressing percentage based on SW than T1, T2 and T4 (Table 5). Except for the dressing percentage

**Table 6.** Partial budget analysis for Abergelle rams supplemented with graded levels of dried mulberry leaf meal and concentrate mix.

| Parameters | Treatments | | | |
|---|---|---|---|---|
| | T1 | T2 | T3 | T4 |
| Number of rams | 6 | 6 | 6 | 6 |
| Purchasing price of ram (ETB/head) | 430.00 | 430.00 | 430.00 | 430.00 |
| Total hay consumed (kg/head) | 42.83 | 44.05 | 45.90 | 44.35 |
| Total wheat bran consumed (kg/head) | 36.95 | 28.17 | 19.12 | 9.89 |
| Total noug seed cake consumed (kg/head) | 8.63 | 6.40 | 4.13 | 1.80 |
| Total dried mulberry leaf meal consumed (kg/head) | 0.00 | 12.16 | 22.87 | 34.13 |
| Total feed consumed as fed-basis (kg/head) | 88.41 | 90.78 | 92.02 | 90.17 |
| Cost for hay (ETB/head) | 53.54 | 55.06 | 57.37 | 55.44 |
| Cost for wheat bran (ETB/head) | 155.19 | 118.31 | 80.3 | 41.54 |
| Cost for noug seed cake (ETB/head) | 56.10 | 41.60 | 26.85 | 11.70 |
| Cost for dried mulberry leaf meal (ETB/head) | 0.00 | 30.40 | 57.18 | 85.33 |
| Total cost of supplement (ETB/head) | 211.29 | 190.31 | 164.33 | 138.57 |
| Total feed Cost or TVC (ETB/head) | 264.83 | 245.37 | 221.70 | 194.01 |
| Selling price of ram /Gross return (ETB/head) | 930.83 | 960.83 | 979.17 | 962.50 |
| Total return (ETB/head) | 500.83 | 530.83 | 549.17 | 532.50 |
| Net return (ETB/head) | 236.00 | 285.46 | 327.47 | 338.49 |
| ∆TR | - | 30 | 48.34 | 31.67 |
| ∆TVC | - | -19.46 | -43.13 | -70.82 |
| ∆NR | - | 49.46 | 91.47 | 102.49 |

T1 = ad libitum natural grass hay (NGH) + 100% CM; T2 = ad libitum NGH + 75% CM + 25% DMLM; T3 = ad libitum NGH + 50% CM + 50% DMLM; T4 = ad libitum NGH + 25% CM + 75% DMLM; TVC = total variable costs; ∆TR = change in total return; ∆TVC change in total variable costs and ∆NR = change in net return.

based on SW, the present study result was consistent with the finding of Worku (2015) for SW, empty body weight, hot carcass, RER, total edible offal's and total non-edible offal's for Arsi-bale goats supplemented with graded levels of dried mulberry leaf substituted portions of CM. The difference for dressing percentage based on SW among T3 and T1, T2 and T4 might be due to the numerically higher hot carcass weight score for T3 compared to the rest treatments, and also influence of other factors such as gut content and weight of head. It has been noted that SW is positively correlated with hot carcass weight (Jaramillo et al., 2012).

The ribeye area in the present study was within the range of 8 - 9.4 $cm^2$ reported by Hagos and Melaku (2009) for Afar rams. Ribeye area is affected by the weight and muscularity of the live animal (O'Rourke et al., 2004) and it is increased with carcass weight (Park et al., 2002). The backfat thickness in the present study was slightly lower but within range of of 2.8 - 7 mm reported by Degu et al. (2009) for Tigray highland sheep fed cactus (*Opuntia ficus-indica*)-teff straw and supplemented with isonitrogenous oil seed cakes. The USDA yield grades categorized lamb carcass into five groups with yield grade one having highest expected yield of trimmed retail cuts and backfat thickness ≤ 0.15 inch (3.83 mm), and yield grade five with the lowest yield and ≥ 0.46 inch (11.73 mm) backfat thickness (O'Rourke et al., 2004). According the USDA yield grades, the value of backfat thickness in the present study was classified under the corresponding backfat thickness for yield grade one.

## Partial budget analysis

The result of partial budget analysis as shown in Table 6, revealed that total feed cost reduced with increased amounts of DMLM substitution for CM. Substitution of DMLM for CM minimized total feed cost by 7.35, 16.29 and 26.74% and CM cost by 9.93, 22.23 and 34.42% for T2, T3, and T4, respectively as compared to T1. The net return and change of net return (ΔNR) were linearly increased with increased levels of substitution of DMLM for CM. The ΔNR exhibited a profit of 20.96, 38.76 and 43.43% for T2, T3 and T4 compared to T1, respectively. The increment in net return and ΔNR as the levels of substitution of DMLM for CM increased could be partly attributed to the differences in selling price of the rams but mainly due to lower cost of DMLM as compared to CM.

## Conclusion

All the dietary treatments provided comparable results in terms of growth performance, most nutritional and most carcass parameters measured. However, the net return and ΔNR parameters in the partial budget analysis showed that T4 had highest economical gain. Therefore, substitution of 75% DMLM for CM contained WB and NSC is recommended on both biologically and economically efficient supplementary regime for Abergelle sheep reared by smallholder farmers.

## CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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