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Research Paper

Combinations of *Urochloa* hybrid Mulato II and natural pasture hays as a basal diet for growing Farta lambs in Ethiopia

Combinaciones del híbrido Urochloa *Mulato II y heno de pasto natural como dieta basal para el crecimiento de corderos Farta en Etiopía*

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Abstract

The study was conducted to evaluate the feed intake, digestibility, bodyweight change and carcass characteristics of Farta lambs fed Brachiaria (now: *Urochloa*) hybrid Mulato II and natural pasture hays in various proportions as a basal diet supplemented with a local concentrate mixture (CM). Twenty-five yearling male Farta lambs with a mean initial body weight of 19.6±0.29 kg (mean±s.e.) were used in feeding (90 days) and digestibility (7 days) trials. The lambs were randomly allocated to the following 5 dietary treatments on the basis of stratified body weight: 100% natural pasture hay (NPH) (T1); 75% NPH+25% *Urochloa* hybrid Mulato II hay (MH) (T2); 50% NPH+50% MH (T3); 25% NPH+75% MH (T4); and 100% MH (T5). A local concentrate mixture [300 g dry matter (DM)/hd/d] was fed to all animals. Crude protein (CP) concentration of the basal diet increased as proportion of MH in the ration increased ($P<0.05$). Intake of DM and nutrients, and nutrient digestibility coefficients increased significantly ($P<0.05$) as proportion of MH in the roughage component of the ration increased. Final body weight, average daily bodyweight gain, feed conversion efficiency and most carcass parameters measured were significantly ($P<0.05$) higher as proportion of MH increased from 0 to 100% in the basal diet. Based on the biological performance of the experimental lambs, performance of sheep in the region could be enhanced significantly by incorporating MH with native pasture hay and concentrate supplement in feeding rations. Economic assessments would reveal the optimal combinations of native pasture and MH for feeding to achieve particular outcomes. Other improved grass and legume species may fill the same role and should be investigated in differing environments.

Keywords: Bodyweight gain, *Brachiaria*, carcass yield, digestibility, fattening sheep, tropical grasses.

Resumen

El estudio se realizó para evaluar la ingesta de alimento, la digestibilidad, el cambio de peso corporal y las características de la canal de los corderos Farta alimentados con Brachiaria (ahora: *Urochloa*) híbrido Mulato II y heno de pasto natural en diversas proporciones como dieta basal suplementada con una mezcla de concentrado local (CM). Se utilizaron veinticinco corderos Farta añojos con un peso corporal inicial medio de 19.6 ± 0.29 kg (media ± s.e.) en las pruebas de alimentación (90 días) y digestibilidad (7 días). Los corderos se asignaron aleatoriamente a los siguientes 5 tratamientos dietarios sobre la base del peso corporal estratificado: 100% heno de pasto natural (NPH) (T1); 75% de NPH + 25% de heno de Mulato II *Urochloa* híbrido (MH) (T2); 50% NPH + 50% MH (T3); 25% NPH + 75% MH (T4); y 100% MH (T5). Se alimentó a todos los animales con una mezcla de concentrado local [300 g de materia seca (DM)/hd/d]. La concentración de proteína cruda (CP) de la dieta basal aumentó a medida que aumentó la proporción de MH en la ración ($P <0.05$). La ingesta de DM y nutrientes, y los coeficientes de digestibilidad de los nutrientes aumentaron significativamente ($P <0.05$) a medida que aumentaba la proporción de MH en el componente forrajero de la ración. El

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peso corporal final, la ganancia de peso corporal diaria promedio, la eficiencia de conversión alimenticia y la mayoría de los parámetros de la canal medidos fueron significativamente (P <0.05) mayores a medida que la proporción de MH aumentó de 0 a 100% en la dieta basal. Basándose en el desempeño biológico de los corderos experimentales, el desempeño de los ovinos en la región podría mejorarse significativamente incorporando MH con heno de pasto nativo y suplemento concentrado en las raciones de alimentación. Las evaluaciones económicas revelarían las combinaciones óptimas de pastos nativos y MH para la alimentación para lograr resultados particulares. Otras especies mejoradas de gramíneas y leguminosas pueden desempeñar el mismo papel y deben investigarse en diferentes entornos.

Palabras clave: Aumento de peso corporal, *Brachiaria*, digestibilidad, engorde de ovejas, pastos tropicales, rendimiento en canal.

Introduction

Ethiopia has the largest livestock population among African countries (CSA 2017) and livestock production is an important component of farming systems in all parts of the country, playing a vital role in the livelihood of many people (Tekliye et al. 2018). Sheep production is a major component of the livestock sector in Ethiopia owing to the large population of 30.7 million head (CSA 2017). However, the productivity of livestock in general and sheep in particular is below the African average, mainly due to inadequate supply of feed and poor feeding practices (Mekuriaw and Asmare 2018). To combat the livestock feed shortage, use of improved forage plants as a feed source is recommended (Shapiro et al. 2015; FAO 2016).

Cultivars of *Urochloa* (new generic name of *Brachiaria* species that have provided grass cultivars) are possible candidates to alleviate ruminant feed shortage and thereby enable the country to exploit the potential of livestock resources. Cultivars of this genus are the most extensively grown tropical forages in Latin America, Asia, South Pacific and Australia, with an estimated 99 million hectares in Brazil alone (Jank et al. 2014). Recently, there has been considerable interest in *Urochloa* grasses in Africa, and several initiatives are ongoing to promote the genus to support the emerging livestock industry in the region, especially during the dry season (Maass et al. 2015). Some *Urochloa* species are reported to have several advantages over other tropical grasses including: adaptation to drought and infertile soils; ability to sequester carbon; increased efficiency of nitrogen use through biological nitrification inhibition; and arresting emissions of greenhouse gas, such as methane (Njarui et al. 2016). Currently, *Urochloa* hybrid cv. Mulato II (MH) grass is being used in dual-purpose 'push-pull' technologies (Khan et al. 2014) and as livestock feed in Ethiopia (Adnew et al. 2018). However, there is limited information on performance of animals consuming *Urochloa* grasses, particularly cv. Mulato II, in Ethiopia. Our research hypothesis was that feed value of Mulato II hay would be at least equal to that of natural pasture hay and feed intake, DM digestibility and resultant bodyweight change and carcass characteristics of Farta sheep would be superior for Mulato II hay. Therefore, this study was conducted to evaluate feed intake, digestibility, bodyweight change and carcass characteristics of Farta sheep fed cv. Mulato II and natural pasture hays in different proportions as a basal diet supplemented with a local concentrate mixture.

Materials and Methods

Description of the study area

The experiment was conducted at the Woreta Agricultural College in Ethiopia (11°58′ N, 37°41′ E; 1,774 masl). The experimental area has an annual average temperature of 29°C and annual rainfall ranges from 1,103 to 1,336 mm.

Experimental sheep and their management

Twenty-five yearling intact male Farta sheep with mean body weight (BW) of 19.6±0.29 kg (mean±s.e.) were housed in individual pens equipped with feed and water troughs. Before the commencement of the experiment, sheep were quarantined for 21 days and treated with Ivermectin to control internal parasites and Diazanon to control external parasites. They were also vaccinated against anthrax and pasteurellosis, which are the most common sheep diseases of the area.

Experimental design, treatments and feeding management

The experimental design employed in this study was a randomized complete block design with 5 treatments and 5 replications. Sheep were allocated to treatments by stratified randomization on the basis of initial BW. The treatments used in the study were: 100% native pasture hay (NPH; T1); 75% NPH+25% Mulato II hay (MH; T2); 50% NPH+50% MH (T3); 25% NPH+75% MH (T4); and

100% MH (T5) with equal amounts of concentrate supplement throughout [300 g dry matter (DM)/hd/d]. The concentrate mixture consisted of noug (*Guizotia abissynica*) seed cake and wheat bran in equal proportions. The sheep were offered the basal diet *adlibitum* with amount fed adjusted weekly to allow a 25% refusal. All sheep were fed in individual feed troughs. The natural pasture hay was obtained from farmers and consisted of a mixture of mainly *Andropogon* and *Cynodon* grasses with some contribution by native legumes (*Trifolium* and *Medicago*) (Yalew et al. 2020). The natural pasture was harvested at about 50% heading of the grass according to smallholder farmers' usage. Mulato II grass had been fertilized with diammonium phosphate (DAP) and nitrogen during establishment and was harvested at 4 months of age where it was fully mature and dried under shade.

Feed intake and body weight measurements

Daily feed offered and refusals were recorded for each lamb throughout the study and daily feed intake was calculated as the difference between the amounts offered and refused. Subsamples of feed offered and refusals were taken from each treatment and prepared for chemical analysis. The BW of each animal was measured every 10 days after overnight fasting (without feed only). Initial BW of experimental lambs was measured at the end of the quarantine/adaptation period, while final BW was measured at the end of the feeding trial. Daily BW gain was calculated as the difference between final BW and initial BW divided by the number of feeding days. Feed conversion efficiency (FCE) of experimental animals was determined by dividing the average daily feed consumed by daily BW gain of animals to give amount of feed consumed per unit of weight gained.

The digestibility trial was conducted at the end of the feeding trial. Each sheep was fitted with a fecal collection bag and a 4-day acclimatization period was followed by total collection of feces for 7 consecutive days. The parameters studied were: dry matter intake; dry matter digestibility; organic matter digestibility; and digestibility of individual nutrients. Feces voided were weighed and recorded each morning and thoroughly mixed, before a 20% representative sample was taken, frozen at -10°C and pooled over the collection period for each animal. At the end of the collection period, samples were pooled and mixed thoroughly for each sheep before drying at 60°C for 72 h. The digestibility of individual nutrients was determined as the difference between intake of the nutrient and that recovered in the feces expressed as a proportion of intake of the nutrient.

$$\text{Apparent digestibility \%} = \frac{\text{Nutrient intake} - \text{Nutrient in feces}}{\text{Nutrient intake}} \times 100$$

Carcass evaluation

At the end of the digestibility trial, all experimental lambs were slaughtered after overnight fasting for evaluation of carcass parameters using a standard slaughtering method. Pre-slaughter weight (PSW) of each lamb was recorded immediately before slaughtering. Hot carcass weight (HCW) was measured after removal of blood, skin, head, feet (legs below the hock and knee joints), gastrointestinal tract and internal organs. Based on feeding habits of people in the area, edible and non-edible offals were categorized and recorded. Blood, heart, liver, kidney, tongue, reticulo-rumen, omasum-abomasum, hind-gut, tail fat, kidney fat, pelvic fat, omental and mesenteric fat, testicles and pancreas were weighed and recorded as total edible offals (TEO), while head without tongue, skin, penis, feet, lungs with trachea, spleen, gall bladder with bile, oesophagus, bladder and gut contents were weighed and recorded as total non-edible offals. Total usable product was taken as the sum of HCW, skin and TEO. Empty body weight (EBW) was calculated as the difference between PSW and gut contents. Dressing percentage (DP) was calculated as HCW as a proportion of both PSW and EBW. To measure rib eye-area (REA) of the carcass, the loin part was partitioned into fore- and hindquarters between the 11th and 12th ribs. The cut ribs were chilled for 12 hours and the rib-eye area was measured at the 11–12th rib site (O'Rourke et al. 2005) by tracing first on transparent plastic paper before the traced paper was positioned on graph paper with 1×1mm squares. The number of squares included within the traced area was counted for left and right sides and rib-eye area was computed as the average of the two.

Chemical analysis

Samples of feed, refusals and feces were dried and ground using a laboratory mill to pass through a 1 mm sieve. The DM content was determined by oven-drying samples at 105 °C and organic matter (OM) percentage as the difference between DM percentage and ash percentage. Total nitrogen (N) was determined by the Kjeldahl method (AOAC 1990). Neutral detergent fiber (NDF), acid detergent fiber (ADF) and acid detergent lignin (ADL) concentrations were determined by the method of Van Soest and Robertson (1985).

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 for least square ANOVA. Mean separations were done using polynomial contrasts for variables whose F-values declared a significant difference. Differences were considered statistically significant at P<0.05. The statistical model for data analysis was:

$Y_{ij} = \mu + t_i + b_j + e_{ijk}$,

where:

Y_{ij} is the response variable;
μ is the overall mean;
t_i is the treatment effect;
b_j is the block effect; and
e_{ijk} is the random error.

Results

Chemical composition of feeds

The chemical composition of feeds used in the experiment is presented in Table 1. The natural pasture hay had crude protein (CP) concentration of 6.7%, while the Mulato II hay contained 12.1% CP. As percentage of Mulato II hay in the roughage increased, CP% increased progressively. With fiber and lignin concentrations, the opposite was the case with highest levels in 100% NPH and lowest in 100% MH. The concentrate mixture was a conventional supplement with 22.1% CP.

Dry matter and nutrient intake

The daily DM and nutrient intakes of sheep in the various treatments are presented in Table 2. Total DM and CP intakes increased progressively as proportion of Mulato II in the diet increased (P<0.001).

Bodyweight change and feed conversion efficiency

Bodyweight changes, average daily gain and FCE are presented in Table 3. Average daily gain (ADG) during the feeding period increased from 39.6 g/d for the 100% NPH ration to 82.7 g/d for the 100% MH ration (P<0.001). Correspondingly, FCE improved progressively from 18.5 g dry matter intake (DMI)/g gain for the NPH ration to 10.3 g DMI/g gain for the MH ration (P<0.05), indicating a marked improvement in efficiency of utilization of the rations as proportion of Mulato II in the ration increased.

Dry matter and nutrient digestibility

Table 4 presents the apparent-digestibility coefficients of DM and individual nutrients for the various rations. DM digestibility of the rations increased progressively as the proportion of MH in the rations increased from 62.0% for 100% NPH to 79.0% for 100% MH (P<0.05), while CP digestibility increased from 64.0 to 83.0% for the corresponding treatments (P<0.05). Similar increases in digestibility of NDF (64.0 to 82.0%) and ADF (63.0 to 79.0%) (P<0.05) were recorded for the relevant treatments.

Carcass evaluation

Pre-slaughter weight, empty body weight, hot carcass weight and dressing percentage. Final BW weights and carcass parameters of the experimental animals are presented in Table 5. Pre-slaughter body weight (PSW) mirrored the final BW for the various treatment groups, ranging from 22.5 kg for 100% NPH to 28.8 kg for 100% MH (P<0.001) as did EBW (18.0 to 23.1 kg; P<0.01). In a similar fashion, hot carcass weight (HCW) increased progressively as MH proportion in the ration increased from 9.00 kg for 100% NPH to 12.42 kg for 100% MH (P<0.001). Rib-eye area also increased from 6.06 cm^2 for 100% NPH to 8.28 cm^2 for 100% MH (P<0.05).

Edible and non-edible carcass offals

Total edible offal (TEO) also increased progressively from 3.70 kg for 100% NPH to 4.42 kg for 100% MH (P<0.05), as did total non-edible offal (9.22 to 10.04 kg) but differences between treatments were not significant (P>0.05). In this study, blood, heart, kidney, tongue, omasum-abomasum, hind-gut, tail fat, kidney fat, pelvic fat, omental and mesenteric fat, testicles, pancreas, skin, spleen, gall bladder with bile, bladder and gut contents showed increasing trends as proportion of MH in the ration increased but differences between treatments failed to reach significance (P>0.05; Table 6). However, increases in weight of liver and reticulo-rumen were significant (P<0.05). For non-edible offals, penis, feet and lungs with trachea increased linearly (P<0.05) with increasing proportion of Mulato II hay in the ration.

Table 1. Chemical composition of 4-month-old roughage ingested by Farta sheep fed natural pasture (NPH) and Mulato II (MH) hays alone and in various combinations along with a concentrate mixture (MH).

Treatment[1]	Parameter (%)						
	DM	Ash	OM	CP	NDF	ADF	ADL
T1	94	11.6	88.4	6.7	80.0	66.0	16.5
T2	92	11.6	88.4	7.9	75.3	63.5	15.7
T3	92	11.5	88.5	9.4	74.8	62.2	15.6
T4	93	12.4	87.6	10.5	70.1	59.2	14.9
T5	93	13.5	86.5	12.1	60.1	57.6	14.7
Conc.mix[2]	90.6	8.5	91.5	22.1	37.1	24.3	9.4

DM = dry matter; OM = organic matter; CP= crude protein; NDF= neutral detergent fiber; ADF= acid detergent fiber; ADL= acid detergent lignin; Conc. mix= concentrate mixture.
[1]T1 = 100% NPH; T2 = 75% NPH + 25% MH; T3 = 50% NPH + 50% MH; T4 = 25% NPH + 75% MH; T5 = 100% MH.
[2]A concentrate mixture of 50%noug seed cake: 50% wheat bran was fed at 300 g DM/hd/d on all treatments.

Table 2. Daily dry matter and nutrient intakes of Farta sheep fed natural pasture (NPH) and Mulato II (MH) hays alone and in various combinations along with a concentrate mixture.

Parameter	Treatment					s.e.m.	Sig.	P
	T1[1]	T2	T3	T4	T5			
Total DM intake (g/hd/d)	732d[2]	764c	774c	807b	851a	8.71	***	<0.001
DM intake (% BW)	3.08	3.19	3.31	3.25	3.31	0.00	NS	0.62
OM intake (g/hd/d)	384d	411c	417c	444b	476a	6.79	***	<0.001
CP intake (g/hd/d)	28.4e	36.7d	44.2c	53.1b	66.8a	2.72	***	<0.001
NDF intake (g/hd/d)	346	350	352	356	358	2.32	NS	0.08
ADF intake (g/hd/d)	285b	290b	293b	300ab	317a	3.02	**	0.001

DM = dry matter; OM = organic matter; CP= crude protein; NDF= neutral detergent fiber; ADF= acid detergent fiber; ADL= acid detergent lignin; Conc. mix= concentrate mixture.
[1]T1 = 100% NPH; T2 = 75% NPH + 25% MH; T3 = 50% NPH + 50% MH; T4 = 25% NPH + 75% MH; T5 = 100% MH. A concentrate mixture of 50% noug seed cake: 50% wheat bran was fed at 300 g DM/hd/d on all treatments.
[2]Means within rows with different letters are significantly different.

Table 3. Bodyweight parameters and feed conversion efficiency of Farta sheep fed natural pasture (NPH) and Mulato II (MH) hays alone and in various combinations along with a concentrate mixture.

Parameter	Treatment[1]					s.e.m.	Sig.	P
	T1	T2	T3	T4	T5			
Initial BW (kg)	19.0	19.8	19.2	19.6	20.2	0.29	NS	0.19
Final BW (kg)	22.6b[2]	24.5ab	25.6ab	26.2a	28.0a	0.51	***	<0.001
ADG (g/d/h)	39.6c	52.4bc	71.1ab	73.8ab	82.7a	4.09	**	<0.01
FCE	18.5a	14.6b	10.9c	10.9c	10.3c	0.005	***	<0.001

BW = body weight; ADG = average daily gain; FCE = feed conversion efficiency.
[1]T1 = 100% NPH; T2 = 75% NPH + 25% MH; T3 = 50% NPH + 50% MH; T4 = 25% NPH + 75% MH; T5 = 100% MH. A concentrate mixture of 50% noug seed cake: 50% wheat bran was fed at 300 g DM/hd/d on all treatments.
[2]Means within rows with different letters are significantly different. [3]FCE = DMI/ADG, i.e., g of DMI/g gain.

Table 4. Dry matter and nutrient digestibility coefficients for Farta sheep fed natural pasture (NPH) and Mulato II (MH) hays alone and in various combinations along with a concentrate mixture.

Digestibility coefficient	Treatment[1]					s.e.m.	Sig.	P
	T1	T2	T3	T4	T5			
DM (%)	62.0c[2]	65.0c	74.0abc	76.0ab	79.0a	0.02	***	<0.001
OM (%)	65.0b	69.0ab	74.0ab	76.0ab	79.0a	0.01	***	<0.001
CP (%)	64.0b	72.0ab	75.0ab	77.0ab	83.0a	0.02	***	<0.001
NDF (%)	64.0b	69.0ab	76.0ab	77.0ab	82.0a	0.02	***	<0.001
ADF (%)	63.0b	66.0b	75.0ab	73.0ab	79.0a	0.02	**	0.01

DM = dry matter; OM = organic matter; CP= crude protein; NDF= neutral detergent fiber; ADF= acid detergent fiber.
[1]T1 = 100% NPH; T2 = 75% NPH + 25% MH; T3 = 50% NPH + 50% MH; T4 = 25% NPH + 75% MH; T5 = 100% MH. A concentrate mixture of 50% noug seed cake: 50% wheat bran was fed at 300 g DM/hd/d on all treatments.
[2]Means within rows with different letters are significantly different (P<0.05).

Table 5. Carcass characteristics of Farta sheep fed natural pasture (NPH) and Mulato II (MH) hays alone and in various combinations along with a concentrate mixture.

Parameter	Treatment[1]					s.e.m.	Sig.	P
	T1	T2	T3	T4	T5			
PSW (kg)	22.50c[2]	23.76bc	24.50bc	26.60ab	28.83a	0. 65	***	<0.001
EBW (kg)	18.03c	20.27bc	20.17bc	21.50ab	23.70a	0.56	***	<0.001
HCW (kg)	9.00d	9.83cd	10.43bc	11.20b	12.42a	0.33	***	<0.001
Dressing percentage								
PSWB	40.0	41.4	42.6	42.1	43.2	0.41	*	<0.01
EBWB	49.9	48.7	51.7	49.2	52.5	0.84	NS	0.39
TEO (kg)	3.70b	3.94ab	3.94ab	4.22a	4.42a	0.08	***	<0.001
TNEO (kg)	9.22	9.00	9.32	9.93	10.04	0.21	NS	0.13
REA (cm^2)	6.06b	6.60ab	7.01ab	7.52ab	8.28a	0.25	***	<0.001

PSW = pre-slaughter weight; EBW =empty body weight; HCW =hot carcass weight; PSWB =pre-slaughter weight-basis; EBWB = empty body weight-basis; TEO =total edible offal; TNEO = total non-edible offal; REA = rib-eye area.
[1]T1 = 100% NPH; T2 = 75% NPH + 25% MH; T3 = 50% NPH + 50% MH; T4 = 25% NPH + 75% MH; T5 = 100% MH. A concentrate mixture of 50% noug seed cake: 50% wheat bran was fed at 300 g DM/hd/d on all treatments.
[2]Means within rows with the same letter are not significantly different (P>0.05).

Table 6. Edible and non-edible offal components of Farta sheep fed natural pasture (NPH) and Mulato II (MH) hays alone and in various combinations along with a concentrate mixture.

Parameter	Treatment[1]					s.e.m.	Sig.	P
	T1	T2	T3	T4	T5			
Edible offals								
Blood (mL)	933	1,033	900	1,100	1,000	35.8	NS	0.45
Heart (g)	86.1	83.3	97.7	108.1	105.5	3.9	*	0.02
Liver (g)	230b[2]	290a	293a	289ab	340a	10.5	**	0.00
Kidney(g)	54.1	68.0	65.1	70.0	74.1	2.47	*	0.01
Tongue (g)	141	128	127	111	113	4.7	*	0.04
Reticulo-rumen (g)	546b	522b	574ab	609ab	650a	14.4	**	0.00
Omasum-abomasum (g)	189	191	197	203	220	6.0	NS	0.51
Hind-gut (g)	719	775	812	825	943	27.8	*	0.01
Tail fat (g)	433	440	474	491	501	19.6	NS	0.25
Kidney fat (g)	27.9	26.7	21.3	30.7	27.8	3.64	NS	0.90
Pelvic fat (g)	32.0	25.7	28.9	30.7	36.3	2.04	NS	0.39
Omental and mesenteric fat (g)	57.2	55.1	62.2	62.8	79.3	6.04	NS	0.29
Testicles (g)	230	269	254	261	292	10.6	NS	0.16
Pancreas (g)	26.3	32.4	28.3	31.8	34.5	1.22	NS	0.07
Non-edible offals								
Head without tongue (g)	1,450b	1,495ab	1,401b	1,693a	1,485ab	32.0	NS	0.10
Skin (kg)	1.97	2.07	2.13	2.00	2.27	0.040	*	0.05
Penis (g)	38.1b	49.5ab	44.7ab	43.5ab	66.2a	3.26	*	0.01
Feet (g)	536b	617ab	634ab	621ab	666a	14.1	*	0.00
Lungs with trachea (g)	308b	368ab	317b	340b	466a	17.7	**	0.00
Spleen (g)	40.2	40.0	41.7	35.1	54.8	4.27	NS	0.47
Gall bladder with bile (g)	16.5	20.4	7.3	10.2	18.4	2.48	NS	0.72
Oesophagus (g)	36.5	40.6	45.1	39.6	40.5	1.79	NS	0.62
Bladder (g)	32.8	37.4	26.6	35.5	45.8	3.74	NS	0.41
Gut contents (kg)	4.80	4.27	4.67	5.10	4.93	0.20	NS	0.48

[1]T1 = 100% native pasture hay (NPH); T2 = 75% NPH + 25% Mulato II hay (MH); T3 = 50% NPH + 50% MH; T4 = 25% NPH + 75% MH; T5 = 100% MH. A concentrate mixture of 50% noug seed cake: 50% wheat bran was fed at 300 g DM/hd/d as well.
[2]Means within rows with the same letter are not significantly different (P>0.05).

Discussion

This study has shown the potential benefits of incorporating Mulato II hay with natural pasture hay in preparing rations fed to sheep in Ethiopia, in company with a concentrate supplement. Inclusion of MH in the ration increased performance from moderate weight gains (about 40 g/hd/d) to gains in excess of 80 g/hd/d. The increase in weight gains resulted in heavier sheep at slaughter with higher carcass and offal weights as well as higher levels of fatness of the sheep.

Chemical composition of feeds

The CP concentration of natural pasture hay alone was higher than the CP concentration (3.5% CP) in natural pasture hay reported by Asmare et al. (2016) in northwestern Ethiopia. This disparity in CP concentration could be a function of many factors, e.g., location, soil type, species composition, time of harvesting and post-harvest handling. Nevertheless, CP concentration in the natural pasture hay used in the current study was lower than the 7–7.5% required satisfying the maintenance requirement of ruminants (Van Soest 1982); thus, protein supplement is needed if weight gains are to be achieved.

In contrast, CP concentration in the Mulato II hay could be considered adequate to support weight gains in sheep, even in the absence of the concentrate supplement, as demonstrated by the increase in daily weight gains as proportion of MH in the ration increased. CP concentrations in the diet in excess of 7% ensure a sufficient supply of N for proper functioning of rumen microbes and to meet maintenance requirements of animals and support weight gains (Van Soest 1994), provided other factors such as lignification do not limit feed digestibility and nutrient utilization. The high NDF concentration in native pasture hay (80%) places it as a low-quality feed, since roughage with NDF concentration greater than 65% is categorized in that way (Van Saun 2006). According to McDonald et al. (2010), the NDF portion of feed is only partially digestible by any species of animals, but can be used to a greater extent by ruminants, which depend on microbial digestion for utilization of most fibrous plant components.

Dry matter and nutrient intake

Intakes of natural pasture hay and Mulato II hay obtained in the current study were higher than the values reported for natural pasture hay (Ephrem et al. 2015) plus concentrate supplement, natural pasture hay supplemented with graded levels of *Ficus thonningii* (local name: *Chibha*) leaves and a concentrate supplement (Mekuriaw and Asmare 2018) and Rhodes grass plus a concentrate supplement consumed by Washera sheep (Tefera et al. 2015). Higher intakes of natural pasture hay and Mulato II observed in the current study are probably related to the better overall quality of the roughage component of the ration. The increase in DM intake with increasing level of Mulato II hay in the rations would be a consequence of the higher DM digestibility of the Mulato II hay. As digestibility of DM increases, the rate of passage of ingesta through the digestive tract increases, allowing the animal to consume more feed. Hence mean total DM intake increased significantly ($P<0.05$) from T1 to T5 as the proportion of the more digestible forage, Mulato II hay, in the roughage component of the ration increased. The higher CP concentration of the Mulato II hay would ensure adequate N supply for the microbial population. As Negesse et al. (2001) confirmed, DM intake of sheep increases as the level of CP in the diet increases. The total DM intake expressed as percent of BW obtained from the current study agrees with the results of different authors (Mekuriaw and Asmare 2018; Asmare et al. 2016; Tekliye et al. 2018) and fell within the range of recommended DM intakes of ruminants (2 to 6%) (ARC 1980; Devendra and Burns 1983). DM intake is an important factor in the utilization of roughage by ruminant livestock and is a critical determinant of nutrient and energy intake and performance in small ruminants (ARC 1980). Intake of available energy is a vital factor determining performance of livestock and high DM intakes are essential to achieve high rates of weight gain.

Nutrient digestibility

The significant increase in apparent digestibility of DM and of nutrients as level of Mulato II hay increased from 0 to 100% would be related to the higher CP concentration in Mulato II hay relative to natural pasture hay as well as the lower levels of fiber in the Mulato II hay. The CP digestibility of the various rations in the current study increased significantly as the proportion of Mulato II hay in the ration increased as a reflection of the superior quality of the Mulato II hay and the more active rumen microflora in the presence of additional nutrients, especially N. McDonald et al. (2010) and Negesse et al. (2001) reported that feed which is rich in protein promotes high microbial population, which in turn facilitates rumen fermentation. The increase in digestibility of nutrients with increasing levels of Mulato II in the current study agrees with the findings of Asmare et al. (2016) for Washera sheep fed increasing proportions of desho grass in a native pasture basal diet supplemented with local concentrate mixtures, where digestibility of nutrients increased as proportion of desho grass hay in the basal diet increased.

Body weight and feed conversion efficiency

Better performance of sheep in terms of higher average daily gain as the proportion of Mulato II in the ration increased is a function of a higher intake of a better-quality ration, hence greater nutrient intake. The results of this study agree with the report of Asmare et al. (2016) in which sheep fed on a high protein (208 g/kg DM) diet showed high liveweight gain (36.6 g/d), whereas those fed on a low protein (106 g/kg DM) diet gained only 10.7 g/d. The improvement in FCE as proportion of Mulato II in the ration increased in the current study merely reflects the increasing nutrient concentration in the diet, the higher feed intakes and the consequent increase in bodyweight gains which result. The poor FCE of sheep in the Control treatment (T1) was probably the result of low protein intake and high fiber concentration of the native pasture hay diet, resulting in a greater proportion of feed consumed being required for maintenance, leaving fewer nutrients to support weight gains.

Slaughter weight, hot carcass weight and dressing percentage

In the current study, increases in bodyweight change as proportion of Mulato II in the ration increased were reflected in increases in carcass weight as well. The highest pre-slaughter body weight was recorded in T5 (28.83kg) as was the highest carcass weight (12.42 kg). Dressing percentage also increased as the level of Mulato II in the ration increased despite the weight of some offal components also being directly related to the proportion of Mulato II in the ration. One contributing factor was the absence of any significant difference in weight of gut contents between the different treatments despite animals in T5 eating 16% more dry matter daily than the 100% native pasture hay group and being 28% heavier pre-slaughter. The absence of a greater quantity of gut contents despite greater intake would be a function of faster rate of passage of ingesta in treatments with higher levels of MH. The increase in rib-eye area with increase in level of Mulato II in the ration in the present study (from 6.06 to 8.28 cm^2) was not unexpected as rib-eye area is affected by the weight and muscularity of the live animal (O'Rourke et al. 2005) and increases with carcass weight (Park et al. 2002).

Edible and non-edible carcass offals

In different parts of the country, different proportions of the internal offal including blood are both edible and saleable and are a source of additional income that could add value to the carcass. Due to differences in the eating habits of people in different areas, edible and saleable portions of the offal scan vary depending on the location (Legesse 2001). In the current study, among the offal components classed as edible, the weights of liver and reticulo-rumen increased with increase in Mulato II inclusion in the ration. Similarly, Alemu et al. (2014) and Gebreyohannes et al. (2003) observed significant increase in liver weight with concentrate supplementation. In addition, Lawrence and Fowler (1998) reported an increase in liver weight following supplementation, which they attributed to the storage of reserve substances such as glycogen in the liver in supplemented sheep.

Conclusion

The high CP and relatively lower fiber fractions of Mulato II as produced for this study make it a valuable source of nutrients for feeding to local sheep in Ethiopia. Incorporating it with native pasture hay in conjunction with a concentrate supplement can allow a given amount of this valuable feed to be used to improve the performance of many more sheep than if fed as the sole diet. Other improved species of grass and legumes could provide a similar result and should be evaluated in this and other regions to ensure a wide range of potential sources of fodder.

Conflict of Interest

We certify that there is no conflict of interest with any financial organization regarding the material discussed in the manuscript.

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