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Effects of Supplementing Finger Millet (*Eleucine coracana*) Straw with Grass Pea (*Lathyrus sativus* L.) Hulls and Concentrate Mixture on Feed Intake, Digestibility and Body Weight Change in Washera Sheep

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Abstract

The productivity of sheep in Ethiopia is very low mainly due to a serious shortage of feedstuff. As a result, it is necessary to look for cheap locally available feedstuffs to sustain sheep production in the country. Non-conventional feeds like grass pea (*Lathyrus sativus* L.) hulls (GPH) could partly fill the gap in the feed supply, decrease competition for food between humans and animals and reduce feed cost. Therefore, this experiment was designed to evaluate effects of different proportions of grass pea hulls and concentrate mixture (CM) supplementation on feed intake, digestibility, and growth of Washera sheep fed finger millet straw (FMS) as a basal diet. Diets consisted FMS alone fed *ad libitum* (T1), 100% CM (T2), 30% GPH mixed with 70% CM (T3), 30% CM mixed with 70% GPH (T4), and 100% GPH (T5). For all treatments, FMS was fed *ad libitum*. Experimental sheep were arranged in a randomized complete block design and treatment feeds were assigned to the animals within a block. The results showed that FMS contained 5.5% CP and 68.9% NDF. The supplements contained 21%, 20%, 16% and 14% CP; and 36%, 43%, 52% and 59% NDF for T2, T3, T4 and T5, respectively. Supplementation improved ($p < 0.0001$) DM and nutrient digestibility. Average daily gain (ADG) was 60, 84, 51, and 28 g/day for T2, T3, T4 and T5, respectively, which showed that T3 recorded the highest ADG and T5 resulted in the lowest ADG ($p < 0.0001$). While, animals in T1 lost a bodyweight of 5.6 g/day. As the proportion of GPH supplementation was greater than 30%, there was reduction ($p < 0.05$) in DM intake, DM and CP digestibility and consequently depressed ADG in sheep. Partial budget analysis results showed that net return and change in net return were in the order of T3 > T2 > T4 > T5. Therefore, from biological point of view as well as based on partial budget analysis, T3 was found to be recommendable for smallholder sheep producers.

Keywords

Finger Millet Straw, *Lathyrus sativus* L. Hull, Sheep, Supplementation

1. Introduction

Ethiopia is recognized to possess one of the most diversified indigenous sheep populations in Africa [1] and it is the home for the second largest sheep population in the continent [2]. Sheep contribute a substantial amount to the farm household income, mutton and non-food products, such as manure, skin and coarse wool. However, the productivity of sheep in Ethiopia is very low. For instance, average carcass weight per sheep is estimated to be 10 kg [3] due to limited genetic capacity and mainly environmental factors. Among the environmental factors, the main challenge for the smallholder livestock production in numerous tropical countries like Ethiopia is the inadequate supply and low level of feeding due to a serious shortage of feedstuff.

The predominant feed sources in Ethiopia are natural pastures, crop residues and aftermath grazing. Because of the expansion of cultivation and shrinkage of traditional grazing areas, crop residues are assuming greater importance as sources of roughage feeds than natural pastures in most places. According to studies conducted in some parts of the mixed crop-livestock farming system of Ethiopian highlands, crop residues provide about 50% of the total ruminant livestock feed resource [4] [5], and their contribution could be as high as 80% during the dry seasons of the year. However, crop residues have a very poor feeding value due to their inherent lower nutrient content. These feed resources have been reported to depress feed intake, digestibility, and microbial nitrogen supply. Thus, there is a need for supplement feeds to complement these poor-quality crop residues.

Supplementation of low-quality feed resources with grains can be employed to enhance the energy and/or protein status of low-quality feeds [6] but is rather costly for smallholders. Instead, conventional agro-industrial by-products have been widely used as energy and protein supplements. Nevertheless, periodic shortages and escalating costs of conventional agro-industrial by-products have limited their use by smallholder livestock producers. Non-conventional agro-industrial by-products like grass pea hulls could partly fill the gap in the feed supply, decrease competition for food between humans and animals, reduce feed cost, and contribute to self-sufficiency in nutrients from locally available feed sources.

In Ethiopia, a large amount of grass pea is produced annually. According to CSA [7], in the year 2016, 151,268.58 hectares of land were covered with grass pea. From this hectare of land, about 2,970,972.08 quintals of grass pea were produced. Ethiopian Export Promotion Agency (EEPA) [8], reported that in Ethiopia grass pea is a highly consumed pulse in the daily diet of the society in urban and rural areas. It is eaten whole, split or milled usually fresh, fried, boiled or mixed with other cereals to make various types of stews or soups. Therefore, during the feeding process a considerable amount of hulls, a by-product that can be used as feed for livestock, is produced.

Currently, grass pea is widely cultivated as human feed in Awi zones of Amhara regional state of the study area and produced a considerable amount of by-product. However, information about the feeding value of the grass pea hull in general in Ethiopia and in the study area, in particular, is limited [9]. Therefore, this experiment was designed to evaluate the response of Washera sheep supplemented with different proportions of grass pea hulls together with concentrate mixtures on feed intake, digestibility, body weight change and the profitability of the feeding regime through partial budget analysis fed finger millet straw as a basal diet.

2. Materials and Methods

2.1. Experimental Site

This experiment was carried out in Dangila town at Zubra Abo Kebele, located under the administration of Awi Zone in Amhara National Region State, Ethiopia. Geographically, Zubra Abo kebele is located at an elevation of 2200 m.a.s.l with latitude and longitude of 11˚16'N and 36˚50'E, respectively.

2.2. Experimental Animals and Their Management

All animal handling practices followed the international guiding principles listed by the Council for International Organizations of Medical Sciences and the International Council for Laboratory Animal Science [10].

Twenty-five intact yearling male Washera sheep with mean initial body weight (IBW) of 17.5 ± 2.5 kg (mean ± SD) were purchased from Dangila local market. The age of sheep was determined based on dentition and information obtained from the owners. They were quarantined for 21 days in order to observe their health condition. During this period, the animals were injected with acaricide Ivermectin against internal and external parasites. Sheep were vaccinated against sheep pox and pasteurellosis as per the recommendation of a veterinarian. The experimental animals were identified using neck tags. Animals were randomly placed in an individual pen furnished with feeding troughs and water buckets. At the beginning of the acclimatization period, the weight of each sheep was taken for the two consecutive days after overnight fasting and average values were used to group sheep into five blocks of five animals each. Cleaning of the pens was done daily before placement of the daily ration.

2.3. Feed Collection, Preparation, Experimental Design and Treatments

Finger millet straw was collected from farmers immediately after the threshing of grains. After collection, the straw was stored in a well-ventilated shade until it was used. Grass pea hulls and wheat bran (WB) were purchased from mill factories and noug seed cake (NSC) was purchased from oil processing factories. Then, WB and NSC were mixed in 2:1 ratio, respectively and termed as concentrate mixture (CM). Finger millet straw was offered *ad libitum* as a basal diet allowing a refusal rate of 20%. Graded levels of GPH and CM were offered as treatment diet two times a day at 0800 and 1600 h in equal proportions. Supplements and the basal diet were selected based on availability and extent of use by the farmers. Supplements were formulated to support the maintenance and growth of 30 kg weighing sheep to gain 50 - 100 g per day [11]. Water and mineral lick (salt) were available to the animal all the time.

The design of this experiment was Randomized Complete Block Design (RCBD). The treatments comprised of *ad libitum* FMS alone (T1), FMS *ad libitum* + 100% CM (T2), FMS *ad libitum* + 30% GPH mixed with 70% CM (T3), FMS *ad libitum* + 30% CM mixed with 70% GPH (T4) and FMS *ad libitum* + 100% GPH (T5) (**Table 1**). The supplements were offered on DM basis and each animal received 400 g/day.

2.4. Measurements

2.4.1. Digestibility Trial

The digestibility trial was conducted following 15 days of acclimatization period of the experimental diets and pen. It has lasted 10 days in which 3 days for animals to acclimatize carrying of the fecal collecting bags followed by 7 days feces collection period. Feces were collected every morning for each animal before giving a feed. The daily collected feces from each animal were weighed, mixed thoroughly and 20% was sampled every day and immediately put in refrigerator at −20˚C. At the end of the digestibility trial, composite feces sample of each sheep for 7 days was formed and 10% was subsampled and put in refrigerator at

Table 1. Treatment layout.

Treatments	FMS	CM (g/day)	GPH (g/day)
T1	*Ad libitum*	0	0
T2	*Ad libitum*	400	0
T3	*Ad libitum*	280	120
T4	*Ad libitum*	120	280
T5	*Ad libitum*	0	400

FMS = finger millet straw; CM = concentrate mixture consisted of wheat bran and noug seed cake in the ratio of 2:1; GPH = grass pea hulls.

−20˚C pending chemical analysis. In addition, samples from feed offer and refusals were collected every morning and a composite sample of offer for each feed and refusal per treatment were kept. The composite sub-samples of feces in ice-box container and feed samples were taken to Debre Berhan Research Centre Nutrition Laboratory for chemical analysis.

Apparent digestibility of DM, OM, CP, NDF, and ADF was determined using the following formula.

$$\text{Digestibility}(\%) = \frac{\text{DM or nutrient intakes} - \text{DM or nutrients in feces}}{\text{DM or nutrient intakes}} \times 100$$

where DM = dry matter.

2.4.2. Feed Intake and Live Weight

The feeding trial was conducted following the digestibility trial on the same sheep for a period of 90 days. Daily feed was offered to the experimental animals and the corresponding refusals were measured and recorded during the experimental period to determine daily feed intake. Feed intake was determined by the difference between the amount of feed given and refused every day. Samples of feed offered were taken from batches of feeds and refusals were collected from each animal across the experimental period.

Initial and final body weights of the experimental animals were measured using suspended weighing scale with sensitivity of 50 g at the beginning and at the end of the growth trial. To determine the weight change trend in the course of the experiment, live weight of each animal was taken at every 10 days interval in the morning before provision of feed and water after overnight fasting. ADG for each sheep was determined as a difference between the final and initial weight divided by the total number of actual feeding days.

Feed conversion efficiency (FCE): This is the measure of feed utilization. It was calculated as unit of body weight gain per unit of feed consumed. Thus, the FCE was calculated by the formula;

$$\text{FCE} = \frac{\text{Body weight gain in gram per day}}{\text{DM intake in gram per day}}$$

The substitution rate (SR) of the basal feed by the supplement was calculated using the following equation [12].

$$\text{SR} = \frac{\text{FMS intake alone}(\text{control}) - \text{FMS intake in the supplement treatments}}{\text{Supplement intake}}$$

The metabolisable energy content of treatment feeds was estimated from the digestible organic matter intake of the feeds using the following formula [13].

$$\text{ME}(\text{MJ/day}) = 0.0157 * \text{DOMI g/kg DM}$$

where DOMI g/kg DM = digestible organic matter intake gram per kg dry matter.

2.5. Chemical Analysis

Feces and feed samples (offer and refuse) were dried at 105˚C overnight in a forced draft oven for DM determination. The remaining feeds and feces samples were dried at 60˚C to constant weight and ground through a 1 mm screen for dry matter, total ash and N determination following the procedure of AOAC [14]. Then CP was determined as N X 6.25. Neutral detergent fiber (NDF) and acid detergent fiber (ADF) were determined as per the procedure of Van Soest and Robertson [15]. Organic matter (OM) was calculated as ash deducted from hundred.

2.6. Partial Budget Analysis

The partial budget analysis was carried out for determination of the potential profitability of the feeding regime through the procedure of Upton [16]. Purchasing and selling prices of sheep, cost of basal diet and supplementary feeds (GPH + WB + NSC) were recorded. At the end of the experiment, the selling prices of sheep were estimated by three well experienced sheep dealers and the average price of those dealers was taken as the selling price of the sheep for each treatment. The economic analysis included calculations of total variable costs (TVC) and benefits from selling of sheep. In the analysis, the total return (TR) was determined by the difference between selling and purchasing price of sheep in each treatment. The net return (NR) was calculated by subtracting total variable cost (TVC) from the total return (TR).

$$\text{NR} = \text{TR} - \text{TVC}$$

The change in net return (ΔNR) was calculated as the difference between the change in total return (ΔTR) and the change in total variable cost (ΔTVC):

$$\Delta\text{NR} = \Delta\text{TR} - \Delta\text{TVC}$$

The marginal rate of return (MRR) measures the change in net return (ΔNR) related with each additional unit of costs (ΔTVC). This is expressed as:

$$\text{MRR} = \Delta\text{NR}/\Delta\text{TVC}$$

2.7. Statistical Analysis

The collected data were subjected to the analysis of variance (ANOVA) using the GLM procedure of SAS (version 9.1) [17]. Adjusted Tukey test ($p < 0.05$) was used to locate means that are significantly different. The statistical model used was:

$$Y_{ij} = \mu + a_i + b_j + e_{ij}$$

where, Y_{ij} = the response variable;

μ = overall mean;

a_i = the *i*th treatment effect;

b_j = the effect of *j*th block; e_{ij} = random error.

3. Results and Discussion

3.1. Chemical Compositions of Experimental Feeds

The basal diet FMS contained a CP level (5.5) that could not satisfy the maintenance requirement of ruminants and the NDF and ADF contents were also higher than the level (55%) above which voluntary feed intake was limited [18], indicating a need for supplement feeds to complement this feed stuff (**Table 2**). On the other hand, GPH, concentrate mixture and its ingredients had moderate CP, relatively low level of NDF and ADF values qualify them as potential supplements in animal feeding system where poor quality fibrous feeds are the dominant feed resources.

3.2. Dry Matter and Nutrient Intakes

The results showed that FMS DM intake in the control group was significantly ($p < 0.0001$) higher than in the supplemented groups. The highest FMS intake by sheep in the un-supplemented group as compared to supplemented ones might be due to the low CP and ME contents of FMS used, and as a result of this animals try to consume more FMS to meet their nutrient requirements. The result of the current study is similar to Mulat [19], Ayenew *et al.* [20] and Melese *et al.* [21] who reported higher FMS DM intake of sheep in the un supplemented than the supplemented treatments.

Although the CP and ME contents were low in 100% GPH treatment (T5) than other treatments, sheep consumed lowest basal DM. The reason might be attributed to the higher fibrous nature of the GPH supplement resulted in gut fill which consequently might reduce DM intake. Generally, the current study showed that as the level of GPH supplementation increases in the diet of sheep, the total DM intake depressed.

In case of total DM intake expressed as percent body weight (% BW), significantly lower intake was recorded in un supplemented group than supplemented ones, and significant difference was not observed among supplemented treatments (**Table 3**). In contrary with the current result, Fentie and Solomon [22]

Table 2. Chemical compositions (% for DM and % DM for others) of experimental diets.

Offer	DM	OM	CP	NDF	ADF
FMS (T1)	92.1	89.3	5.5	69.4	48.0
NSC	94.0	88.1	30.0	27.0	22.0
WB	89.3	96.0	16.3	40.3	10.1
T2 (CM 33% NSC 67% WB)	91.2	93.0	21.0	36.2	14.4
T3 (CM 70%: GPH 30%)	91.0	94.2	20.0	43.0	23.2
T4 (CM 30%: GPH70%)	90.0	93.0	16.1	52.0	34.0
T5 (GPH)	90.0	96.0	14.4	59.0	43.0

DM = dry matter; OM = organic matter; CP = crude protein; NDF = nutrient detergent fiber; ADF = acid detergent fiber; GPH = grass pea hulls; NSC = noug seed cake; WB = wheat bran; T1 = FMS *ad libitum (*alone*)*;T2 = FMS *ad libitum* + 400 g CM; T3 = FMS *ad libitum* + 280 g CM + 120 g GPH; T4 = FMS *ad libitum* + 280 g GPH + 120 g CM; T5 = FMS *ad libitum* + 400 g g GPH; FMS = finger millet straw; CM = concentrate mixture composed of WB and NSC at a ratio of 67:33, respectively.

Table 3. Daily DM and nutrient intakes of Washera sheep fed FMS basal diet and supplemented with different proportions of GPH and CM.

Intakes	Treatments					SEM	p
	T1	T2	T3	T4	T5		
FMS (g/day)	552^{a}	489^{bc}	507^{b}	472^{bc}	451^{c}	21.5	<0.0001
Supplement (g/day)		400	400	400	400	0.0	
Total DM (g/day)	552^{c}	889^{ab}	907^{a}	872^{ab}	851^{b}	21.5	<0.0001
Total DM (% BW)	3.3^{b}	4.4^{a}	4.4^{a}	4.3^{a}	4.4^{a}	0.36	<0.0001
OM (g/day)	491^{c}	805^{ab}	824^{a}	798^{ab}	783^{b}	19.1	<0.0001
CP (g/day)	30^{e}	109^{a}	102^{b}	89^{c}	80^{d}	1.2	<0.0001
NDF (g/day)	381^{c}	476^{b}	479^{b}	532^{a}	545^{a}	25.4	<0.0001
ADF (g/day)	263^{e}	290^{d}	332^{c}	361^{b}	386^{a}	10.3	<0.0001
ME (MJ/day)	4.0^{c}	9.6^{ab}	9.8^{a}	9.5^{ab}	9.2^{b}	0.22	<0.0001
Substitution rate		0.16^{ab}	0.11^{b}	0.2^{ab}	0.25^{a}	0.058	<0.0001

a-e means with in a row not bearing common superscript are significantly different ($p < 0.05$). OM = organic matter; CP = crude protein; NDF = neutral detergent fiber; ADF = acid detergent fiber; ME = metabolizable energy; SEM = standard error of mean; T1 = FMS *ad libitum* (control); T2 = FMS *ad libitum* + 400 g CM; T3 = FMS *ad libitum* + 280 g CM + 120 g GPH; T4 = FMS *ad libitum* + 120 g CM + 280 g GPH; T5 = FMS *ad libitum* + 400 g GPH; CM = concentrate mixture (67% WB + 33% NSC); GPH = grass pea hull; FMS = finger millet straw.

and Birhanu *et al.* [23] reported higher total DM intake (as % BW) in unsupplemented than the supplemented Farta and Blackhead Ogaden sheep, respectively. However, the daily DM intake as percent BW (3.3% - 4.4% BW) in current study was within the range of 2% - 6% recommended by the ARC [11] for growing sheep.

The CP intake of the experimental animals follows similar trend with the CP contents of the treatment diets in order of T2 > T3 > T4 > T5 > T1 ($p < 0.0001$), whereas OM intake follows similar trend with total DM intake (**Table 3**). The reason for lower CP intake in T5 among the supplemented groups might be due to the fact that the lowest CP content of GPH (14%). However, the CP intake in all supplemented treatments can support 50 - 100 g/day daily gain for growing sheep weighing up to 30 kg [11]. The substitution rates in the current study was ranged from 0.11 - 0.25 (**Table 3**). Among supplemented treatments, T5 had highest substitution rates. This was due to supplementation with a 100% GPH depressed basal diet intake because of high NDF and ADF content.

3.3. Apparent Digestibility of Dry Matter and Nutrients

The results indicated that significant treatment difference in apparent DM, OM, CP ($p < 0.0001$) and NDF ($p < 0.01$) digestibility between supplemented and un supplemented treatments (**Table 4**). Among supplemented groups, the apparent

Table 4. Apparent digestibility (%) of dry matter and nutrients of Washera sheep fed finger millet straw basal diet and supplemented with different proportion of grass pea hulls and concentrate mixture.

Digestibility	Treatments					SEM	p
	T1	T2	T3	T4	T5		
DM	65^{c}	81^{ab}	84^{a}	77^{b}	76^{b}	4.71	<0.0001
OM	52^{b}	76^{a}	76^{a}	76^{a}	75^{a}	6.05	<0.0001
CP	54^{d}	80^{ab}	83^{a}	69^{b}	65^{c}	6.87	<0.0001
NDF	53^{b}	68^{a}	65^{ab}	71^{a}	73^{a}	8.01	0.0065
ADF	54^{b}	54^{b}	52^{b}	61^{a}	61^{a}	5.50	0.0436
Digestible nutrient intake							
DM	358.8^{d}	720^{b}	762^{a}	671^{c}	647^{c}	16.96	<0.0001
OM	254^{c}	612^{ab}	626^{a}	607^{ab}	586^{b}	14.26	<0.0001
CP	16^{e}	87^{a}	84.7^{b}	61^{c}	52^{d}	0.72	<0.0001
NDF	210^{e}	326^{d}	311^{c}	379^{b}	398^{a}	10.07	<0.0001
ADF	141^{d}	156^{d}	173^{c}	220^{b}	234^{a}	5.79	<0.0001

a-e means with in a row not bearing common superscript are significantly different ($p < 0.05$). OM = organic matter; CP = crude protein; NDF = neutral detergent fiber; ADF = acid detergent fiber; SEM = standard error of mean; T1 = FMS *ad libitum* (control); T2 = FMS *ad libitum* + 400 g CM; T3 = FMS *ad libitum* + 280 g CM + 120 g GPH; T4 = FMS *ad libitum* + 120 g CM + 280 g GPH; T5 = FMS *ad libitum* + 400 g GPH; CM = concentrate mixture (67% WB + 33% NSC); GPH = grass pea hull; FMS = finger millet straw.

digestibility of DM in T3 was significantly higher ($p < 0.0001$) as compared to T4 and T5, while other treatments were similar among each other. Numerically higher digestibility value for T3 supplemented sheep compared to the rest of sheep fed other the treatment diets indicate that T3 supplement had potential to improve the digestibility of the basal diet.

The DM digestibility of the supplemented groups in the present study was higher than 61% - 67% reported by Ayenew *et al.* [20] and 52% - 55% documented by Mulat [19] for sheep fed a basal diet of FMS and supplemented with different types of feeds. The DM digestibility in the present study was also higher than the values (67% - 68%) reported by Tesfaye and Solomon [24] in Afar sheep fed teff straw basal diet supplemented with graded levels of CM.

The higher DM digestibility in the present study compared to the previous studies might be attributed to the high CP content of the supplement diets and thereby high CP intake. Ammerman *et al.* [25] found that nitrogen intake was a major factor influencing the intake and digestibility of low quality roughages by ruminants. McDonald *et al.* [26] remarked that concentrate feed rich in protein promotes high microbial population which in turn facilitates rumen fermentation.

The apparent digestibility of CP was significantly higher (p < 0.0001) for T3 compared to T4, and T5 in the supplemented groups. Moreover, lower (p < 0.0001) CP digestibility value was recorded for T5 among the supplemented treatments. The results in the apparent digestibility of this study generally showed that replacing CM with GPH up to 30% level brought significantly higher digestibility of DM and CP and had equal potential with 100% CM for OM digestibility. Over all, GPH up to 100% replacement level of CM significantly improved DM and nutrient digestibility as compared to the control treatment.

3.4. Body Weight Change and Feed Conversion Efficiency

The body weight change (BWC), FBW, ADG and FCE were highly significant (p < 0.001) in supplemented groups than unsupplemented one (**Table 5**). The ADG in T1 was −5.6 g/day, the reason was the poor CP content (5.5%) and high NDF (68.9%) and ADF (47.8%) contents of FMS, which is unable to fulfill the maintenance requirements of the sheep. Consequently, animals undergo substantial mobilization of body reserves to meet nutrient requirements for basic physiological processes at times when they are in negative protein and energy balance [26]. The body weight loss experienced in the present experiment was observed also in the previous studies [19] [20] [24] when they fed different types of crop residues alone for sheep.

Among the supplemented treatments significant different was observed for FBW, BWC, ADG and FCE (p < 0.001) (**Table 5**). The highest (p < 0.001) ADG values were recorded in T3 and T2 supplemented sheep. Similarly, the highest FCE was recorded in T3 and T2 compared to the rest treatments. The significant difference observed in performance among sheep receiving different treatment feeds reflects that supplements were vary in their potential to supply nutrients

Table 5. Body weight change of Washera sheep fed finger millet straw as a basal diet and supplemented with different proportion of grass pea hulls and concentrate mixture.

Parameters	Treatment					SEM	p
	T1	T2	T3	T4	T5		
IBW(kg)	17.12	17.4	17.4	17.6	17.5	1.53	0.9897
FBW (kg)	16.6^{c}	22.8^{ab}	25^{a}	22.2^{ab}	20^{b}	1.51	<0.0001
BWC(kg)	-0.5^{d}	5.4^{ab}	7.6^{a}	4.6^{b}	2.5^{c}	1.25	<0.0001
ADG (g/day)	-5.5^{d}	60.4^{ab}	84^{a}	51.1^{b}	27.6^{c}	13.93	<0.0001
FCE	-0.01^{d}	0.07^{ab}	0.09^{a}	0.06^{b}	0.03^{c}	0.02	<0.0001

a-d means with in a row not bearing common superscript are significantly different (p < 0.05). IBW = body weight; BWC = body weight change; ADG = average daily gain; FCE = feed conversion efficiency; FBW = final body weight; SEM = standard error of mean; T1 = FMS *ad libitum* (control); T2 = FMS *ad libitum* + 400 g CM; T3 = FMS *ad libitum* + 280 g CM + 120 g GPH; T4 = FMS *ad libitum* + 120 g CM + 280 g GPH; T5 = FMS *ad libitum* + 400 g GPH; CM = concentrate mixture (67% WB + 33% NSC); GPH = grass pea hull; FMS = finger millet straw.

for improving the weight gains and FCE of the sheep. Differences in animal performance among treatments in this study were also consistent with differences in total DM intake and digestibility.

The highest ADG (84 g/day) recorded in the current study was higher than 63, 64 and 49 g/day (the highest values in their study) reported by Ayenew *et al.* [20] and Hunegnaw and Birhan [27]. Comparable to the present finding, 82 g/day ADG was observed by Fentie and Solomon [22] for Farta sheep supplemented with 300 g/day (WB and NSC 1:2 ratio, respectively) in hay basal diet. The variations in ADG among studies might be due to difference in breed type, initial body weight of the experimental animals, amount and type of supplement feed, feed processing methods and the environment in which the experiment was conducted.

Trends in BWC during the feeding trial indicated that Sheep in the un supplemented treatment lost body weight throughout the experimental period, while there was a consistent increase in body weight of animals in the supplemented groups (**Figure 1**).

3.5. Partial Budget Analysis

The highest net return (NR) was gained from T3 (231 Ethiopian birr (ETB)/sheep followed by T2 (121 ETB/sheep), T4 (88 ETB/sheep) and T5 (80 ETB/sheep) (**Table 6**). The highest NR in this study was comparable to 203 ETB/sheep reported by Hunegnaw and Birhan [27], higher than Mesganaw [28],who reported 148 ETB/sheep fed grass hay *ad libitum* + 235 g field pea hull. The change in NR was also higher for T3, and the value of marginal rate of return (MRR) in the present study found to be positive for all supplemented treatments. It was highest for T3 followed by T2. The MRR indicated that an additional unit of 1 ETB per lambs cost increment resulted 1 birr and 2.15 for T3, 1.4 birr for T2, 1.35 birr benefit for T4 and T5.

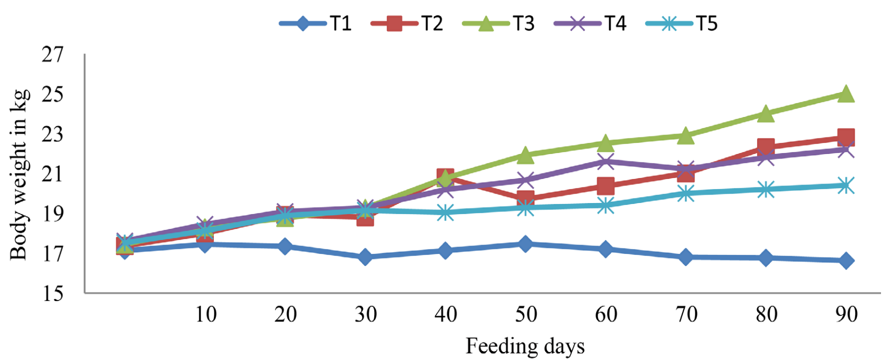

Figure 1. Body weight change over time of Washera sheep fed finger millet straw alone and supplemented with different proportion of grass pea hull and Concentrate mixture. T1 = FMS *ad libitum* (control); T2 = FMS *ad libitum* + 400 g CM; T3 = FMS *ad libitum* + 280 g CM + 120 g GPH; T4 = FMS *ad libitum* + 120 g CM + 280 g GPH; T5 = FMS *ad libitum* + 400 g GPH; CM = concentrate mixture (67% WB + 33% NSC); GPH = grass pea hull; FMS = finger millet straw.

Table 6. The partial budget analysis of Washera sheep fed finger millet straw and supplemented with different proportion of grass pea hulls and concentrate mixture.

Parameters	Treatments				
	T1	T2	T3	T4	T5
Number of sheep	5	5	5	5	5
Purchasing price of sheep	850	840	826	840	826
Total basal DM intake(kg/sheep)	61	54	55	51	49
Wheat bran DM intake(kg/sheep)	-	24	17	7	-
Noug seed cake DM intake(kg/sheep)	-	12	8	4	-
Grass pea hull DM intake(kg/sheep)	-		11	25	36
Total concentrate DM intake(kg/sheep)	-	36	36	36	36
Cost of basal diet (ETB/head)	94.55	84	85	80	76
Cost of wheat bran (ETB/head)	-	108	76	32	-
Cost of noug seed cake (ETB/head)	-	64	45	19	-
Cost of grass pea hull (ETB/head)	-	-	48	111	158
Total cost of concentrate (ETB/head)		172	168	162	158
Total variable cost (ETB/head)	95	259	253	242	235
Selling price of sheep (ETB/head)	835	1220	1310	1170	1140
Total return (ETB/head)	−15	380	484	330	314
Net return(ETB/head	−110	121	231	88	80
Change in net return (ETB/head)		231	341	198	189
Change in total variable cost		164	158	147	140
Marginal rate of return(ΔNR/ΔTVC)		1.40	2.15	1.34	1.35

ETB = Ethiopian birr; TR = total return; ΔNR = change in net return; ΔTVC = change in total variable cost; MRR = marginal rate of return; T1 = FMS *ad libitum* (control); T2 = FMS *ad libitum* + 400 g CM; T3 = FMS *ad libitum* + 280 g CM + 120 g GPH; T4 = FMS *ad libitum* + 120 g CM + 280 g GPH; T5 = FMS *ad libitum* + 400 g GPH; CM = concentrate mixture (67% WB + 33% NSC); GPH = grass pea hull; FMS = finger millet straw.

4. Conclusion

The results of this study indicated that supplementation of poor quality diet like FMS with nonconventional feeds like GPH together with conventional agro-industrial by-products (noug seed cake and wheat bran) improve both total DM and CP intakes, and CP digestibility, which in turn resulted in weight gain of growing sheep. Grass pea hulls can replace wheat bran and noug seed cake mixture (mixed with 2:1 ratio in that order) up to 30% inclusion level and it was found to be recommendable for smallholder farmers.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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Abbreviations

ADF: Acid Detergent Fiber; ADG: Average Daily Gain; AFRC: Agricultural Food and Research Council; CP: Crude Protein; CSA: Central Statistical Agency; DM: Dry Matter; DMI: Dry Matter Intake; ETB: Ethiopian Birr; EEPA: Ethiopian Export Promotion Agency; FCE: Feed Conversion Efficiency; FMS: Finger Millet Straw; GPH: Grass Pea Hulls; ME: Metabolisable Energy; MRR: Marginal Rate of Return; NDF: Neutral Detergent Fiber; NSC: Noug Seed Cake; WB: Wheat Bran