



Dried-*Atella* as an affordable supplementary feed resource for a better sheep production: in the case of Washera lambs in Ethiopia

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ABSTRACT

Ethiopia has a huge livestock population that includes sheep, which can be considered as a significant potential for the advancement of the country's economy. However, due to a shortage of appropriate supplementary feed and its escalating price, the production and productivity of sheep fattening in Ethiopian smallholder farmers are below its potential. Moreover, the use of Dried-*Atella* as an affordable supplementary feed resource for a better sheep production is not investigated and well documented. The aim of this study was to assess the comparative supplementation effects of Dried-*Atella* and Niger seed cakes (NSCs) on total dry matter and nutrient intake, body weight change, and carcass characteristics of Washera lambs. The experiment was conducted using a completely randomized design with three treatments replicated five times. The treatments are described as follows: Treatment 1 = Natural pasture hay (NPH) (800 g/d) + Wheat bran (WB) (160 g/d) + salt and water (ad libitum); Treatment 2 = NPH (800 g/d) + WB (160 g/d) + NSC (163 g/d) + salt and water (ad libitum); and Treatment 3 = NPH (800 g/d) + WB (160 g/d) + Dried-*Atella* (330 g/d) + salt and water (ad libitum). The finding elucidated that the crude protein (CP) content of Dried *Atella*, WB, NPH, and NSC were about 25.07%, 16.57%, 4.48%, and 38.04%, respectively. The result also indicated that the average mean value of the feed and CP intake of the sheep fed Dried-*Atella* was significantly higher than the other treatments (P -value = 0.000). With regard to the CP digestibility and dry matter digestibility, animals supplemented with Dried-*Atella* were significantly higher than the control group with P -value = 0.000 and P -value = 0.028, respectively. The body weight gain of the sheep is significantly higher (P -value = 0.008) for feeds supplemented with Dried-*Atella* than feeds without any supplement. In terms of economic profitability, a slightly better benefit was recorded in feed supplements with Dried-*Atella* than supplements with NSC, animal feed without any supplement exhibited loss. Considering its effect on feed intake, CP intake, and its digestibility, body weight gain, and carcass characteristics of lambs, Dried-*Atella* is a promising affordable supplementary feed resource for better sheep production in Ethiopia.

Key words: dried-*Atella*, economic analysis, Niger seed cake, nutrient intake, Washera lambs

INTRODUCTION

Ethiopia has diversified agro-ecological conditions with various species of domestic and wild animals that significantly contribute to the national economy. The country is endowed with a huge livestock population including sheep. Among the total livestock production, sheep production is a major component of the livestock sector in Ethiopia (Tadesse et al., 2020). In Ethiopia, the estimated sheep population is more than 30 million (FAO, 2019). About 40% of the total livestock populations of the country are found in the Amhara region. The estimated sheep and goat population of the Amhara region is about 8.4 million, and most of the producers in the region prefer sheep fattening over goat fattening (Mekuria et al., 2018). In the Amhara region, Washera breeds are predominantly used because of their fast growth rate, including weight gain than other breeds (Getachew et al., 2017). The lower risks, short generation interval, and relatively smaller requirement of initial investment inspire most of the rural farmers as well as peri-urban and urban dwellers to get involved in the

sheep fattening activities (Selamawit and Matiws, 2015). However, feed shortage and its escalating price are limiting the sheep productivity in all parts of the country (Hizkel et al., 2008; Yenesew et al., 2013; Matawork and Mitiku, 2017). Therefore, to avoid this problem and help the sheep fattening business of the rural poor farmers, it is important to look for alternative feed supplements that can be available in the vicinity at an affordable price. Niger seed cake (NSC) is one of the oilseed cakes commonly used as a protein supplement in the diet of farm animals in Ethiopia. It is mostly cultivated in different regions of Ethiopia and India and comprises around 50% and 3% oilseed production of the countries, respectively (Bhagya and Shamanthaka, 2003). Another potential byproduct called *Atella* is a clear, traditional alcoholic beverage which is distilled from a fermentation product called *Tella*. However, since NSC is relatively becoming less accessible due to low seed yield and high price of the case, it was vital to seek alternative supplement for growing lambs in the country. Hence, the use of the relatively cheap and accessible supplement, *Atella* was included in the current study. *Atella* is the major cheap

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non-conventional feed supplement resource in Ethiopia in general and in the Amhara region in particular (Mekuria et al., 2018; Gizaw et al., 2017). NSC and Atella have relatively high crude protein (CP) and are supposed to provide the required nutrients for growing lambs and because of this reason we want to assess *in vivo* effects using local animals. Our hypothesis was that *Atella* and NSC have a similar supplementary effect on nutrient utilization, body weight change, and carcass characteristics of growing Washera lambs. Therefore, the objective of this study was to evaluate the comparative supplementation effects of Dried-Atella and NSCs on nutrient intake, body weight change, carcass characteristics, and socioeconomic feasibility of Washera lambs.

MATERIALS AND METHODS

Description of the Study Area

The study was conducted on the Zenzelma Campus of Bahir Dar University farm. Zenzelma is one of the kebeles (*Kebele* is lower-level administrative unit in Ethiopia) in Bahir Dar Zuria Woreda, West Gojjam Zone of Amhara region, Ethiopia. According to Zenzelma kebele agricultural office (2017), the area is geographically located between 11°35'N and 11°40'N latitude 37°24'E and 37°29' E longitude with a latitudinal range of 1917 above mean sea level.

Experimental Animals and Their Management

Fifteen male Washera sheep with an average age of less than 1 yr (from 9 mo to 1 yr) but greater than 6 mo and with an average initial body weight of 21.02 ± 1.42 kg was purchased from the local market of *Adet* town. And then, the sheep was quarantined for 21 d. During this quarantine period, each animal was treated against internal parasites by Albendazole and external parasites by Ivermectin. Animals were continuously observed for the incidence of any disease during the observational period. The animal's management was conducted according to Bahir Dar University Research and Community service protocol, ethical review board.

Treatments and Experimental Design

In the treatment supplement formulation, the basal diet hay, salt, and water were offered as adlib. The supplements were given considering the requirements of a 20 kg of tropical growing sheep should receive approximately 69 g to 145 g of CP per day for maintenance (Ranjhan, 1980). Based on these, the treatment combinations were the following:

The treatments were T1 = NPH(adlib) + WB (160 g); T2 = NPH (Adlib) + WB (160 g) + NSC (163 g); T3 = NPH(Adlib) + WB (160 g) + *Atella* (330 g).

In the current experiment, a completely randomized design with five replications has been applied to set apart the different treatments for the sheep. In this experiment, three different supplements/diets were tested on three treatment groups consisting five replications per treatment for 3 mo. The basal diet and supplements were offered separately for each lamb during the experimental period, and refusals were also measured for each individual lamb in treatments. The experiment consisted 90 d of growth and 11 d of digestibility trials, including 15 d of initial feeding trial and 3 d of fecal adaptation periods.

Data Collection

Feed intake Natural pasture hay (NPH) that has been used as a basal diet was chopped into 5 to 10 cm of height to improve its palatability. The feed offered and refused was measured daily using a sensitive balance, and the difference between the daily total feed offered, and the daily feed refused by each sheep was considered as daily feed intake on DM basis. At the end of the experiment, representative samples of offered and refused basal diet as well as feces pooled samples were taken to the laboratory for the chemical analysis of each treatment.

Digestibility After 90 d of adaptation and feeding trial, by using similar dietary treatments, a digestibility trial was followed by using feces collecting bag fitted to each experimental sheep. The sheep had been allowed to a 3-d adaptation period for fecal bags. Feces were collected daily for seven consecutive days from each experimental sheep and pooled over treatments. The feces were then mixed thoroughly, and 20% of daily feces output of each sheep were taken and bulked per treatment and taken to the laboratory for the chemical analysis of each fecal samples. Based on that, the apparent digestibility coefficient of DM, Organic Matter (OM), CP, Neutral Detergent Fiber (NDF), and Acid Detergent Fiber (ADF) was determined by McDonald et al. (2010).

Chemical composition analysis Representative samples of feeds offered, refused, and feces were analyzed for their dry matter and nutrient contents. The samples were dried in an oven and milled using a laboratory miller to pass through a 1-mm sieve screen and then analyzed for DM and ash content according to the procedure of AOAC (2005). Then, the two-stage method indicated by (Tilley and Terry, 1963) was followed to determine IVOMD and then metabolizable energy (ME) content was estimated using the equation: ME (MJ/kg DM) = $0.16 \times \text{IVOMD}$ (McDonald et al., 2010). Nitrogen content was determined using Kjeldahl procedure, and CP was determined as $N \times 6.25$. NDF, ADF, and Acid Detergent Lignin (ADL) were analyzed following the recommendation of Van Soest and Robertson (1985).

Body weight change and feed conversion efficiency The body weight of the lamb was measured in 9 d of intervals after overnight fasting. Body weight gain (BWG) was determined as a difference between the final and initial body weight. The feed conversion efficiency was calculated as a proportion of daily BWG to daily feed intake.

$\text{FCE} = \text{ADG in kg/dry matter intake (DMI) in kg} / \text{BWG} = \text{final body weight} - \text{initial BWG}$

Partial Budget Analysis

The partial budget analysis was employed using the procedure of Upton (1979). All costs related to feed preparation were added to the total variable cost. At the end of the experiment, experienced lamb dealers estimated the selling price of the sheep. The difference between the purchasing and selling price of the sheep in each treatment was considered as total return (TR). The net income (NI) was calculated by subtracting the total variable cost (TVC) from the TR. The change in net income (ΔNI) was calculated as the difference between the change in TR (ΔTR) and the change in total variable cost (ΔTVC). The marginal rate of return (MRR) measures the increase in net income (ΔNI) associated with each

additional unit of expenditure (total variable cost) (Δ TVC). $MRR (\%) = \Delta NI / \Delta TVC \times 100$.

Carcass evaluation To determine the carcass characteristics of experimental lambs, all the experimental lambs from each treatment were deprived of feed and water overnight and weighed before slaughter, and this weight was considered as slaughter weight (SW). According to the local people's meat consumption tradition, offals from lambs were classified as non-edible, edible offals, and main carcass components. The non-edible offal components are the head without tongue, skin, feet, penis, spleen, lung with trachea, gall bladder, esophagus, pancreas, bladder, and gut content. On the other hand, the edible offal components comprise blood, heart, liver, kidney, tongue, reticulo-rumen, omaso-abomasum, hind gut, kidney fat, pelvic fat, omental, and mesenteric fat, and testis, and the main-carcass components contain forequarters, neck region, sternum brisket, thoracic and lumbar region, rib-eye muscle, abdominal muscle, hind quarters, pelvic (rump) region, tail fat weight, and ribs. All components were weighed, recorded, and documented separately. Empty body weight (EBW), hot carcass weight (HCW), rib-eye muscle area, and dressing percentage (DP) were determined individually for each lamb. Whereas calculation of rib-eye muscle area was accomplished by tracing the cross-sectional areas of the 12th and 13th ribs after cutting perpendicular to the backbone. Fat thickness over rib-eye muscle area per each experimental sheep was measured by using a ruler, and the mean of the two sides was considered as fat thickness. The dressing percentage was calculated as proportions of HCW to SW and EBW. The selling price of the sheep was estimated by the consumers before the slaughter of the sheep, which was used to compare the profitability of sheep fattening with different feed supplements.

Statistical Analysis

In this study, the statistical package for social sciences version 26 was used to analyze the data collected. Before analysis, the normality test was conducted using Shapiro-Wilk test. Data on feed intake, digestibility, weight gain, and carcass parameters were analyzed by compare means and analysis of variance. Multiple comparisons (least significance difference) were used to summarize the significant difference between each treatment means. P -values ≤ 0.05 and P -values ≤ 0.001 were considered as highly significant and significant.

The model employed for this experiment was:

$$Y_{ij} = \mu + \tau_j + \varepsilon_{ij}$$

where Y_i is the response variable, μ is the population mean, τ_i is the treatment effect, and ε_{ij} is the random error.

RESULTS

Chemical Composition of Treatment Feeds

The finding revealed that NSC had higher DM, Ash, and CP content than the rest of the treatments, while NPH had a greater NDF, ADF, and ADL content but lower CP content than the rest of the treatments (Tables 1 and 2). On the other hand, the CP content of the offered feed was higher than that of the refusal diet.

Table 1. Chemical composition of NPH and supplements intakes

Chemical composition (g/kg for DM and g/kg DM for others)				
Parameters	NPH	WB	NSC	Atella
DM	914	913.5	939	933.6
OM	884	954.7	859.6	886.7
Ash	117	45.3	140.4	113.3
CP	44.8	165.7	380.4	250.7
NDF	742.1	420.5	423.1	317.5
ADF	508.1	226.4	269.5	83.1
ADL	86.6	40.4	69	81.4

Table 2. Chemical composition of NPH and supplements refusals

Chemical composition (g/kg for DM and g/kg DM for others)			
Parameters	NPH	NPH	NPH
DM	915	912	919
OM	893	904	896
Ash	107	96.5	104.2
CP	39.7	39.4	37
NDF	757	737.5	767.6
ADF	502.1	511	508
ADL	91	92.4	92.1

Feed and Nutrient Intake

The result indicated that no significant difference (P -value = 0.075) was observed in basal DMI among the three treatments (Table 3). In contrast, there was a significant difference (P -value = 0.000) across the three treatments for total DMI, organic matter intake, and crude protein intake (CPI).

Dry Matter and Nutrient Digestibility

According to this investigation, a significantly higher (P -value = 0.000) crude protein digestibility coefficient (CPDC) was retrieved from Dried-Atella-supplemented groups (Table 4). On the contrary, significantly lower (P -value = 0.000) CPDC was recorded from the non-supplemented groups.

Body Weight Change and Feed Conversion Efficiency

According to this finding, although the lambs had almost the same initial average body weight, at the end of the feeding trial, the final average body weight of T_3 groups became significantly heavier than T_2 (P -value = 0.025; Table 5). The feed conversion efficiency documented from T_3 was also significantly higher than T_1 and T_2 (P -value = 0.025).

Carcass Component

According to this result, significantly higher SW (P -value = 0.039), EBW (P -value = 0.001), and HCW (P -value = 0.045) were achieved by T_3 than T_1 groups (Table 6). Regarding the rib-eye muscle area, no significant

Table 3. Feed intake of Washera lambs fed NPH as a basal diet and supplements

Parameters	Treatments			SE	P-value
	T ₁	T ₂	T ₃		
Basal DMI, g/d	474.51 ^a	429.40 ^a	456.93 ^a	17.88	0.075
WB DMI, g/d	146.16	146.16	146.16	0.00	
NSC DMI, g/d	0	153.06	0	0.00	
Atella DMI, g/d	0	0	308.09	0.00	
Total DMI, g/d	620.67 ^a	728.61 ^b	911.17 ^c	17.88	0.000
Total DMI, %BW	2.8 ^a	3.0 ^{ab}	3.5 ^c	0.001	0.000
TOMI, g/d	559 ^a	650.69 ^b	816.64 ^c	15.81	0.000
TCPI, g/d	41.91 ^a	90.18 ^b	109.70 ^c	0.71	0.000
TNDFI, g/d	369.96 ^a	396.03 ^{ab}	445.16 ^{bc}	11.73	0.000
TADFI, g/d	244.72 ^a	259.92 ^a	259.53 ^a	8.03	0.140
TADLI, g/d	41.96 ^a	47.59 ^{ab}	62.85 ^c	1.37	0.000
TashI	61.66 ^a	77.92 ^b	94.53 ^c	2.08	0.000
MEI, MJ/kg DM	6.61 ^a	9.37 ^{ab}	12.28 ^c	0.71	0.000

a b c letters in the same row having different superscripts are significantly different at $P \leq 0.001$; in the same row having different superscripts are significantly different at $P \leq 0.001$ and $P < 0.05$. Estimated ME (MJ/kg DM) = $0.16 \times \text{IVOMD}$.

ADFI = Acid detergent intake; ADLI = Acid detergent intake; NDFI = Neutral detergent intake; OMI = organic matter intake; WB = Wheat bran; were T₁ (Treatment number 1) = NPH(adlib) + WB (160 g); T₂ (Treatment number 2) = NPH (Adlib) + WB (160 g) + NSC (163 g); T₃ (Treatment number 3) = NPH(Adlib) + WB(160 g) + Atella (330 g).

Table 4. Apparent digestibility coefficient of nutrients in sheep fed NPH a basal diet and supplements intakes

Parameters	Treatments			SE	SL	P-value
	T1	T2	T3			
DMDC	0.6509 ^a	0.6984 ^a	0.7249 ^a	0.02955	-	0.076
OMDC	0.6658 ^a	0.7101 ^a	0.7414 ^a	0.02837	-	0.060
CPDC	0.6262 ^a	0.7870 ^b	0.8331 ^{bc}	0.02737	***	0.000
NDFDC	0.6798 ^a	0.6373 ^a	0.6873 ^a	0.03096	-	0.259
ADFDC	0.6582 ^a	0.6203 ^a	0.6295 ^a	0.03364	-	0.521
ADLDC	0.5121 ^a	0.5631 ^a	0.6281 ^a	0.04107	*	0.046

a b c letters in the same row having different superscripts are significantly different at $P \leq 0.001$; in the same row having different superscripts are significantly different at $P \leq 0.05$.

ADFDC = acid detergent fiber digestibility coefficient; CPDC = crude protein digestibility coefficient; DMDC = dry matter digestibility coefficient; NDFDC = neutral detergent fiber digestibility coefficient; OMDC = organic matter digestibility coefficient.

* indicates significant difference between treatments; *** indicates a strong significant difference between the treatments; SE = Standard error, SL = significance level, Atella, T₁ = NPH + 160 g WB; T₂ = NPH + 160 g WB + 163 g NSC; T₃ = NPH + 160 g WB + 330g Atella.

difference was found between T₁ and T₂ as well as in fat thickness across the treatments. The highest dressing percentage (% SW) was recorded for T₃ compared to T₁ and T₃.

Edible Carcass Component

Based on this finding, there was no significant difference ($P > 0.05$) in the average mean of blood, heart, kidney, tongue, omasum abomasum, hind gut, kidney fat, omental mesenteric fat, and testicle across the three treatments (Table 7).

Non-edible Carcass Component

As this finding showed, a significant difference ($P \leq 0.05$) was recorded for penis, lung with trachea, and feet across the three treatments (Table 8).

Main Carcass Component

The average mean of the neck region, sternum, thoracic and lumbar, rib-eye region, abdominal muscle, hind quarters, pelvic, fat tail, and ribs were higher for T₃, while a lower average mean weight was recorded for T₁ (Table 9).

Partial Budget Analysis

Table 10 illustrates the net profit obtained from this investigation. According to this finding, there was loss of money recorded in T₁, while the largest net profit was obtained in T₃ followed by T₂. Similarly, the higher benefit-cost ratio was recorded for T₃, whereas the lowered benefit cost was recorded for T₁.

DISCUSSION

Chemical Composition of Treatment Feeds

The DM, OM, and CP contents of NPH offered in this study were lower than the findings of Feyissa et al. (2015) and Mekuria et al. (2018). The CP content found from this study was also lower than the CP (8%) requirement of ruminants recommended for meeting the maintenance requirement and the optimum microbial activity (6% to 8%; Tadesse et al., 2014; Matawork and Mitiku, 2017). The basal diet (NPH) CP alone in the current study did not fulfill the maintenance requirements of lambs even at the initial stage of growth of lambs, the late stage of growth, otherwise demand more CP for maintenance. Hence, it is possible to declare that the current basal diet must have been supplemented with protein sources to fulfill maintenance and growth requirements of lambs. The variation in the chemical composition of NPH might be due to the different stages of maturity at the time of harvesting, storage condition, plant species of parent crops, and moisture content of the hay. Besides this, the CP, NDF, ADF, and ADL contents of the offered feed were higher than the refused. This could be associated with the better nutritious part of the plants selected and eaten by the experimental lambs. The value of DM and OM of WB obtained from this study agrees with the finding of Mekuriaw and Asmare (2018) who performed the experiment in the same study area. The ash content recorded in this study was lower than the report of Gatenby (1986), but it was comparable with the result of Gebrehiwot et al. (2017). The CP content of WB obtained from this study was approximately similar to the findings of Tadesse et al. (2014) and Gebrehiwot et al. (2017). In contrast to the result of this study, a lower CP was obtained by Mekuriaw and Asmare (2018) and Tulu et al. (2018). The deviation in the nutrient content of WB is possibly because of processing and the quality of the original grain used in the milling industries. The CP (38.04%) content of NSC found from this research was higher than the discovery of Tadesse et al. (2014), Ayele et al. (2017), and Duguma et al. (2019). The fluctuation in the chemical composition of NSC reported by different sources could be due to the difference in the WB processing method used by producers to produce NSC and environmental variation where the nouge seed was produced. The DM content

Table 5. Live weight parameters and feed conversion efficiency of Washera sheep fed grass hay basal diet, NSC and *Atella*

Body weight changes	Treatments			P-value
	T ₁	T ₂	T ₃	
Initial body weight, kg	21.02 ^a ± 2.331	21.04 ^a ± 1.152	21.02 ^a ± 0.531	1.000
Final body weight, kg	22.20 ^a ± 2.248	24.2 ^{ab} ± 1.288	25.80 ^{bc} ± 1.703	0.025
Body weight change, kg	1.18 ^a	3.16 ^b	4.78 ^c	0.000
Average body weight gain, g/d	15.7 ^a	42.1 ^b	63.7 ^c	0.000
Feed conversion efficiency, kg ADG/kg DMI	0.026 ^a	0.061 ^b	0.070 ^{bc}	0.000

Table 6. Live weight parameters of Washera sheep fed grass hay as a basal diet and, supplemented with NSC and *Atella*

Parameters	Treatments			SE	P-value
	T ₁	T ₂	T ₃		
SW, kg	22.37 ^a ± 2.51	24.82 ^{ab} ± 1.66	26.12 ^{bc} ± 1.57	1.241	0.045
EBW, kg	16.73 ^a ± 1.37	18.86 ^b ± 1.41	19.84 ^{bc} ± 0.91	0.791	0.043
HC, kg	8.86 ^a ± 0.72	10.15 ^{ab} ± 1.39	10.80 ^{bc} ± 0.68	0.624	0.038
Dressing percentage, % SW	39.4	40.9	41.4		
Dressing percentage, % EBW	53	53.8	54.4		
Fat thickness, cm ²	0.32 ^a ± 0.13	0.30 ^a ± 0.07	0.50 ^a ± 0.32	0.13	0.520
Rib eye area, cm ²	7.9 ^a ± 0.67	8.87 ^{ba} ± 1.52	10.62 ^c ± 0.65	0.652	0.020

a b c letters in the same row having different superscript are significantly different at $P \leq 0.05$; in the same row having different superscript are significantly different at $P \leq 0.05$.

* indicates significant difference between treatments; ** depicts a strong significant difference between the treatments.

Table 7. Edible offal components of Washera sheep fed grass hay as a basal diet supplemented with *Atella* and NSC

Edible offal	Treatments			
	T ₁	T ₂	T ₃	P-value
	Mean ± SD	Mean ± SD	Mean ± SD	
Blood	0.873 ^a ± 0.071	0.844 ^a ± 0.071	0.964 ^a ± 0.256	0.056
Heart	0.091 ^a ± 0.014	0.101 ^a ± 0.007	0.105 ^a ± 0.010	0.066
Liver	0.245 ^a ± 0.021	0.295 ^b ± 0.011	0.308 ^{bc} ± 0.024	0.044
Kidney	0.057 ^a ± 0.006	0.063 ^a ± 0.007	0.063 ^a ± 0.005	0.061
Tongue	0.115 ^a ± 0.015	0.112 ^a ± 0.012	0.102 ^a ± 0.019	0.053
Reticulorumen	0.535 ^a ± 0.075	0.624 ^b ± 0.056	0.547 ^{abc} ± 0.025	0.065
Omasum abomasum	0.277 ^a ± 0.0216	0.264 ^a ± 0.012	0.307 ^a ± 0.074	0.058
Hind gut	0.808 ^a ± 0.168	0.808 ^a ± 0.053	0.951 ^a ± 0.055	0.067
Kidney fat	0.023 ^a ± 0.006	0.034 ^a ± 0.019	0.026 ^a ± 0.017	0.065
Pelvic fat	0.028 ^a ± 0.007	0.029 ^a ± 0.013	0.053 ^c ± 0.013	0.041
Omental mesenteric fat	0.028 ^a ± 0.007	0.041 ^a ± 0.021	0.046 ^a ± 0.024	0.053
Testicle	0.207 ^a ± 0.050	0.248 ^a ± 0.064	0.258 ^a ± 0.054	0.054

SD = Standard Deviation.

Means followed with different superscripts in a column are significantly different ($P \leq 0.05$).

of *Atella* recorded in this study was comparable with the finding of different authors (McDonald et al., 2010; Tulu et al., 2018). Though, the ADL and ash content of the present analysis was higher than the report of (McDonald et al., 2010). In contrast, higher CP than the following authors

(Van Soest and Robertson, 1985; Tulu et al., 2018) was registered in the current work. The nutrient content variation could be due to divergences in the methods and ingredients used for the preparation of *Atella* (a brew made locally).

Feed and Nutrient Intake

In this study, significantly lower total DMI was recorded in T₁ groups of animals than the rest of the treatment groups. This might be due to the additional DM obtained from the supplemented feed and the higher digestibility of supplemented feed which fermented quickly and gave a space for forage intake. On the other hand, markedly enhanced total DMI was achieved in the T₃ group than in the T₂ group of animals. This might be associated with the discrepancy in the amount of a supplement provided and the inconsistent quantity of basal diet ingested by the animal. The CPI of the supplemented group of animals had a significantly higher CPI than the control (non-supplemented) group. The outcome of the current study matches with many previous studies, such as Tekliye et al. (2018), Duguma et al. (2019), and Znabu et al. (2019), which demonstrated that supplementation boosts the CPI of the sheep. This could be tied to the superior CP content of supplemented feeds and the total DMI of the supplemented group of animals. The supplemented group of animals had significantly greater MEI than the non-supplemented group of animals. Even so, in the comparison between the supplemented groups of animals, T₃ had significantly higher MEI than T₂. The maintenance and growth (50 to 200 g gain) ME requirement for 20 kg lamb is about 4.5 to 7.9 MJ/d (ARC, 1980). Hence, the predicted MEI of the sheep obtained from this

Table 8. Non-edible offal components of Washera sheep fed grass hay as a basal diet supplemented with *Atella* and NSC

Non edible offal	Treatments			P-value
	T ₁	T ₂	T ₃	
	Mean ± SD	Mean ± SD	Mean ± SD	
Head without tongue	1.214 ^a ± 0.152	1.208 ^a ± 0.102	1.277 ^a ± 0.101	0.065
Skin	2.271 ^a ± 0.185	2.960 ^b ± 0.089	2.880 ^{bc} ± 0.120	0.024
Penis	0.059 ^a ± 0.008	0.067 ^b ± 0.018	0.064 ^c ± 0.004	0.022
Feet	0.575 ^a ± 0.035	0.550 ^b ± 0.039	0.573 ^c ± 0.028	0.004
Lung with trachea	0.322 ^a ± 0.032	0.316 ^b ± 0.061	0.354 ^c ± 0.052	0.026
Spleen	0.027 ^a ± 0.003	0.036 ^b ± 0.008	0.040 ^{bc} ± 0.007	0.041
Gall bladder with bile	0.015 ^a ± 0.004	0.015 ^a ± 0.003	0.015 ^a ± 0.004	0.067
Esophagus	0.058 ^a ± 0.030	0.040 ^a ± 0.013	0.041 ^a ± 0.010	0.065
Gut content	5.640 ^a ± 1.169	5.960 ^a ± 1.212	6.280 ^a ± 0.954	0.063
Bladder	0.014 ^a ± 0.003	0.023 ^{ab} ± 0.007	0.035 ^{bc} ± 0.025	0.030
Pancreas	0.030 ^a ± 0.004	0.031 ^a ± 0.004	0.033 ^a ± 0.010	0.066

SD = Standard deviation.

Means followed with different superscripts in a column are significantly different ($P \leq 0.05$).

* indicates significant difference between treatments; ** depicts a strong significant difference between the treatments.

Table 9. Main carcass components of Washera sheep fed grass hay as a basal diet supplemented with *Atella* and NSC

Main carcass component	Treatments			P-value
	T ₁	T ₂	T ₃	
	Mean ± SD	Mean ± SD	Mean ± SD	
Forequarter	2.281 ^a ± 0.238	2.610 ^b ± 0.230	2.520 ^{ab} ± 0.217	0.044
Neck region	0.603 ^a ± 0.076	0.667 ^{ab} ± 0.071	0.698 ^{bc} ± 0.050	0.025
Sternum	0.323 ^a ± 0.054	0.337 ^a ± 0.071	0.454 ^c ± 0.056	0.034
Thoracic and lumbar	0.542 ^a ± 0.015	0.587 ^a ± 0.060	0.663 ^c ± 0.051	0.038
Rib-eye region	0.523 ^a ± 0.086	0.649 ^{ab} ± 0.074	0.670 ^{bc} ± 0.113	0.056
Abdominal muscle	0.360 ^a ± 0.076	0.418 ^{ab} ± 0.054	0.448 ^{bc} ± 0.041	0.009
Hind quarter	2.540 ^a ± 0.219	2.670 ^{ab} ± 0.228	2.900 ^{bc} ± 0.141	0.007
Pelvic	0.704 ^a ± 0.084	0.752 ^a ± 0.061	0.760 ^a ± 0.061	0.015
Fat tail	0.475 ^a ± 0.112	0.830 ^b ± 0.229	1.105 ^c ± 0.192	0.044
Ribs	0.523 ^a ± 0.048	0.565 ^a ± 0.067	0.579 ^a ± 0.060	0.063

SD = Standard deviation.

Means followed with different superscripts in a column are significantly different ($P \leq 0.05$).

* indicates significant difference between treatments; ** depicts a strong significant difference between the treatments.

study (6.61 MJ/d to 12.28 MJ/d) was within the range of the above-mentioned energy demand of the animals used for maintenance and growth. Generally, supplementation of NPH with 330 g DM of *Atella* resulted in a better total DMI and nutrient intake.

Table 10. Partial budget analysis of Washera sheep fed grass hay as a basal diet supplemented with *Atella* and NSC

Variables	Treatments		
	T ₁	T ₂	T ₃
Number of animals	5	5	5
Benefits			
Gross income (selling price of the sheep) (USD)	85.28	97.60	98.23
Total benefit (A)	85.28	97.60	98.23
Costs that vary			
Total purchasing price of sheep (USD) (C)	57.17	57.49	58.75
Total basal diet cost (USD) (D)	6.54	5.82	6.59
Total supplement cost (USD) (E)	4.07	8.5	7.07
Total transportation cost (Sheep and Feed) (F)	5.27	5.27	3.16
Total medication cost (G)	3.16	3.16	3.16
Total labor cost(USD) (H)	10.87	10.87	10.87
Total cost (USD) (B) = (C + D + E + F + G + H)	87.08	91.11	89.6
Net benefit (A-B)	-1.8	6.49	8.63
Benefit cost ratio(A/B)	0.98	1.07	1.1

Dry Matter and Nutrient Digestibility

In this study, a higher nutrient digestibility was indicated in the supplemented group of animals than non-supplemented animals. In the same manner, [Teklehaymanot \(2019\)](#) and [Ayenew et al. \(2012\)](#) also stated enhanced nutrient digestibility among supplemented animals than non-supplemented animals. In the present study, a significant difference in CPDC between supplemented and non-supplemented treatment groups was spotted. The reason could be in ruminant nutrition, the CP from supplement diets might have improved microbial efficiency to enhance fermentative digestion as the microbes' efficiency usually improved through supplementation, as stated by [McDonald et al. \(2010\)](#). This finding was similar to the earlier studies of [Tulu et al. \(2018\)](#) and [Znabu et al. \(2019\)](#). Perhaps, this is associated with the increased nutrient supply, especially nitrogen to rumen microbes. On the other hand, the digestibility of nutrients in T₃ was better than in T₂ animals. This is probably associated with the higher CPI of T₃ of animals, which leads to better CPDC.

Live Weight Change and Feed Conversion Efficiency

In line with the current study, the finding of [Gatenby \(1986\)](#), [Rodriguez et al. \(2014\)](#), and [Teklehaymanot \(2019\)](#) documented a greater final body weight and daily weight gain in the supplemented animals than the non-supplemented animals. This could be due to the essential nutrients provided to rumen microorganisms by supplementary feeds to improve the microbial activity in the rumen. The final BWG recorded in the present study was superior to the findings of different studies ([Worku et al., 2015](#); [Mekuriaw and Asmare, 2018](#); [Mekcha et al., 2019](#)). In contrary to this, the higher body weight gain than the current work was recorded by [Shigdaf et al. \(2013\)](#) and [Mengistie et al. \(2009\)](#), who reported 28.77 kg and 31.04 kg, respectively. In the present analysis, higher ADG (63.7 g/d) was attained as compared to the ADG (45 g/d) of Washera sheep fed grass hay and supplemented with 330 g of sun-dried *Atella* reported by ([Abreham et al.,](#)

2019). Moreover, in this study, an increase in BWG of 0.70 kg was obtained as compared to the research of [Worku et al. \(2020\)](#).

Carcass Component

Similar to the current finding, in the previous studies of [Assefa et al. \(2015\)](#), [Abebe and Tamir \(2016\)](#), and [Worku et al. \(2020\)](#), an increased SW, EBW, HCW, DP, and rib eye area were reported. In this study, better SW was performed by the T₃ group as compared to T₂. This is possibly associated with the higher Feed Conversion Efficiency (FCE) and BWG performed by supplemented animals. In the present investigation, the dressing percentage based on EBW was higher than the dressing percentage based on SW. This shows the influence of digesta (gut full) on dressing percentage. The supplemented treatment groups of this study achieved a higher rib-eye muscle area than the non-supplemented groups. Similarly, the previous study of [Ayele et al. \(2018\)](#), [Duguma et al. \(2019\)](#), and [Worku et al. \(2020\)](#) depicted a positive effect of supplementation on the rib-eye muscle area. However, in the current study among the supplemented group of animals, the greater rib-eye muscle area was achieved by T₃ followed by the T₂ animals. This variation might be associated with the higher live weight gain of the T₃ group of animals. The greater fat thickness obtained from the T₃ group of animals might be associated with the higher total DMI, MEI, and digestibility of nutrients.

Edible Carcass Component

The current study revealed that there was no significant difference in terms of weight of kidney fat and omental mesenteric fat except for pelvic fat among the three treatments. This could be associated with the MEI and energy content of the feed provided. However, the kidney fat and Omental mesenteric fat obtained from this result were higher than the finding of [Mekcha et al. \(2019\)](#), but according to the current finding, but smaller than reports of [Tekliye et al. \(2018\)](#).

Non-edible Carcass Component

Based on this study, the gut content was higher in the supplemented groups than non-supplemented groups. Similarly, [ARC \(1980\)](#) reported an increase in the gut content through supplementation. This might be involved with the higher total DMI of the supplemented group of lambs.

Main Carcass Component

In the present finding, the supplemented sheep had significantly higher fat tail weight than the non-supplemented groups. This might be linked with the lowered total MEI of the control group of animals. This statement agreed with the report of [Tesfaye et al. \(2011\)](#) and [Fitwi and Tadesse \(2013\)](#) who reported a higher weight of tail fat among the supplemented experimental animals.

Partial Budget Analysis

Considering the benefit-cost ratio of these inquiries, a higher benefit-cost ratio was recorded from T₃ followed by T₂. This means that for every 1 USD investment for the fattening of Washera sheep fed grass hay as a basal diet supplemented with *Atella* and NSC, there was a gain of about 1.1 USD (T₃) and 1.07 USD (T₂), respectively. This implies the net benefits of T₃ are 30% higher than the net benefits of T₂. To conclude, supplementation

of NPH with 330 g DM of *Atella* resulted in a better net profit than supplementation of NPH with 163 g DM of NSC. Hence, supplementation of NPH with 330 g DM of *Atella* was found to be potentially more practicable and economically more feasible for smallholder farmers engaged in sheep fattening.

Conclusion

Supplementation of NPH with 330 g DM of *Atella* resulted in a better total DMI, nutrient intake, and a higher net profit than supplementation of NPH with 163 g DM of NSC. Hence, supplementation of NPH with 330 g DM of *Atella* was found to be potentially more practicable, affordable, and economically more feasible for smallholder farmers engaged in sheep fattening. However, further work is required to look into the effect of supplementation of NPH with NSC and NPH with *Atella* on fatty acid profile analysis, the physicochemical composition of meat, and meat composition. In addition to this, a higher digestibility of ADL was recorded in T₃ than T₂. Hence, the authors suggest that further study would be important to investigate the reason behind the higher digestibility of ADL, which might be associated with the breed or the capability of anaerobic fungi.

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AUTHOR CONTRIBUTIONS

All authors contributed in research conceptualization, experimental design, data collection and analysis, and final draft manuscript writing.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interest in the publication of this paper.

ETHICS APPROVAL

Not applicable.

CONSENT TO PARTICIPATE

Not applicable

CONSENT FOR PUBLICATION

All authors agreed on the publication of this paper and assigned corresponding author responsible in charge for correspondence during manuscript publishing.

DATA AVAILABILITY

Data is available with the corresponding author upon request.

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