EFFECT OF SWEET POTATO LEAF SUPPLEMENTATION ON GROWTH AND NUTRIENT DIGESTIBILITY IN SHEEP*

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The effects of feeding dried sweet potato (*Ipomoea batatas*) leaf (SPL) on growth performance, digestibility, and nitrogen (N) utilization were studied in sheep. Twenty-four rams with initial body weight of 18.5 ± 1.49 kg were randomly allocated to four treatments containing *ad libitum* natural grass hay alone (T1), hay + 150 g SPL (T2), hay + 300 g SPL (T3) and hay + 450 g SPL (T4) on as fed basis. Results indicated that dry matter (DM), organic matter (OM) and crude protein (CP) intakes increased ($P < 0.001$) with increasing levels of SPL. Sheep fed with T2, T3 and T4 diets gained 55.1, 52.6 and 66.5 g per head per day, respectively, while the gain of non-supplemented sheep (9.19 g per head per day) differed ($P < 0.05$). Digestibility of DM, OM, and CP was higher ($P < 0.01$) for all supplemented sheep compared with the control. The CP digestibility and N retention were negative in non-supplemented sheep. Urinary N excretion decreased ($P < 0.001$) with the increasing levels of SPL supplementation. The N retention improved with the increasing levels of SPL and was the highest ($P < 0.001$) in sheep fed with T4 diet and the lowest in non-supplemented sheep. In conclusion, supplementing a basal diet of natural grass hay with SPL considerably improved the average daily gain, OM and CP digestibility and N retention.

apparent digestibility, *Ipomoea batatas* leaf, nutrient intake, nutrient utilization, weight gain, natural grass hay

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INTRODUCTION

Supplementing basal feeds that are deficient in major nutrients with either grain concentrate or forage legumes can improve the performance of sheep and goats (Yinnesu, Nurfeta, 2012). However, under smallholder farmer's condition supplementing poor quality feeds with grain concentrate is mostly unaffordable and expensive. One way of improving the utilization of poor quality feed is through supplementation with leaves of multipurpose tree species (Gebregiorgis et al., 2012; Melesse et al., 2015, 2016), which are affordable and easily accessible by farmers. One of such feeds could be sweet potato leaf (SPL), which is cheaper and readily available than concentrates.

Traditionally, sweet potato is cultivated for the production of tubers, and the foliage is considered as an affordable source of protein for livestock under a smallholder production system (Aregheore, 2004). It may be fed to all domestic animal species, both ruminants and non-ruminants. The most important sweet potato parts for animal feeding are the vine, leaf, stem, and root. In some countries, sweet potato leaves and vines are used as animal feed, especially in feeding small stock like pigs, goats, sheep, and its distribution is highly commercialized (Abonyi et al., 2012; Megersa et al., 2013).

Sweet potato is adapted to a wide range of environmental conditions, and it produces a high yield per unit area. According to Woolfe (1992), the yield of foliage on fresh bases is about 36 t ha^{-1}; such quantities could be doubled in tropical areas like Ethiopia where two crops per year are possible. The value of sweet potato is attributed to high yield, palatability and crude protein (CP) content. These characteristics make

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it a suitable protein supplement for animals receiving low quality forage in the dry season (Megersa et al., 2013). The tubers have high carbohydrate content while the leaves are rich in protein, and both tubers and leaves can be used as animal feed (Woolfe, 1992; Melesse et al., 2018). The vines include the leaf and stem, with CP content of 260–330 g kg^{-1} dry matter (DM) in the leaves compared with 100–140 g kg^{-1} DM in the stems (Ishida et al., 2000; An et al., 2003; Megersa et al., 2013). Recent studies conducted by Melesse et al. (2018) on local sweet potato leaves reported relatively high levels of CP (247 g kg^{-1} DM), 68.6 g kg^{-1} DM sugar and 23.9 g kg^{-1} DM starch. The same authors reported higher levels of micronutrients, particularly iron and manganese, as well as energy (11 kJ kg^{-1} DM) as compared to leaves of other root crops. Moreover, no soluble condensed tannins were detected in sweet potato leaves making it a suitable feed resource for ruminant nutrition (Melesse et al., 2018). It has been shown that the leaves make up approximately half of the sweet potato vines biomass (Woolfe, 1992; An et al., 2003). If the leaves are separated from the stems, a considerable improvement with respect to the dietary protein and amino acid supply would be expected (An et al., 2003). Studies conducted by Megersa et al. (2013) reported that sweet potato vine can replace the conventional concentrate and could be fed with poor quality hay to prevent body weight loss of animal in the absence of other feed supplements. However, to the authors' knowledge, there is little information available on the feeding potentials of varying levels of sweet potato leaves on the growth performances of sheep when supplemented to the basal diet of grass hay. Under small-scale production systems, farmers feed whatever amount of sweet potato leaves without considering how much the animals consume and how much they require. Therefore, it is important to determine the optimum level of supplementation, which can support a better response in sheep feeding under small-scale sheep production practices. Therefore, this study was conducted with the objective of evaluating the effect of supplementing increasing levels of SPL on body weight gain, feed intake and digestibility in sheep fed a basal diet of natural grass hay.

MATERIALS AND METHODS

Experimental site

The experiment was conducted at Hawassa University, School of Animal and Range Sciences which is situated at 7°4′ N latitude and 38°29′ E longitude and at 1650 m a.s.l. The rainfall pattern of the area is bi-modal ranging between 700 and 1200 mm annually. The mean minimum and maximum temperatures in the area are 13.5 °C and 27.6 °C, respectively (National Meteorological Agency of Ethiopia, http://www.ethiomet.gov.et).

Experimental diets

Fresh sweet potato leaves (SPL) were obtained from farmers and were harvested manually and air dried for 3–5 days on a concrete floor covered with plastic sheet. Then, the dried leaves were ground and stored in sacks until used. Natural grass hay was purchased from surrounding farmers and chopped prior feeding to the sheep. The grass hay and SPL was fed separately.

Experimental animals

Twenty-four yearling local Arsi-Bale rams with an average initial body weight of 18.46 ± 1.49 kg were purchased from the local market. The sheep had adapted to the experimental environment for 2 weeks before the commencement of the experiment. The sheepfold had a corrugated metal sheet roof and a concrete floor. The sheep were housed in individual pens with a concrete floor and fed using separate feeding troughs. Before starting the experiment, the sheep were treated with acaricides and albendazole to control external and internal parasites, respectively.

Experimental design

The sheep were weighed before the start of the feeding regime and divided into four groups of six animals; weighed and randomly allocated to dietary treatments in a completely randomized design (CRD). The four dietary treatments used were: T1, *ad libitum* grass hay (basal diet); T2, grass hay + 150 g SPL per head per day; T3, grass hay + 300 g SPL per head per day; T4, grass hay + 450 g SPL per head per day.

The sheep were allowed 14 days of adaptation to experimental environment, 14 days to the respective experimental diets and the actual data collection lasted for 70 days. Clean water was supplied *ad libitum*. Daily feed offered to the experimental animals and the corresponding refusals of each animal were measured and recorded during the experimental period to determine daily feed intake. SPL supplements were offered separately, twice a day in two equal portions at 8.00 h and 16.00 h. The basal diet was offered *ad libitum*.

The initial body weight of each animal was determined by taking the mean of two consecutive weights after overnight fasting at the beginning of the feeding trial. Body weight was then taken on weekly basis before morning feeding. The body weight taken at the end of the experiment was considered as final body weight. The body weight gain was then calculated as the difference between the final and initial body weights divided by the number of days of the feeding trial.

A digestibility trial was conducted after the end of the growth experiment using the same animals.

Experimental sheep were first allowed to adapt to the fecal collection bags and urine collection harnesses for 3 days followed by the actual data collection for 7 days. The feeding regime was the same as in the preceding growth experiment. Daily feed intake and output of feces and urine were recorded and representative samples were collected for further processing. Feces from each sheep were collected into fecal bags attached to the sheep every morning before feeding and weighing. Then, 10% of the daily fecal output from the 7-day collection period was taken and bulked in a freezer. Separate samples of feces were dried daily at 105 °C overnight to determine the dry matter (DM) content. Similarly, daily total urine output of each sheep was collected in bottles containing 100 ml of 10% hydrochloric acid. Ten percent of the samples collected each day was taken and stored in a freezer. At the end of the experiment, samples of feces and urine were kept at room temperature and allowed to thaw for 24 h before sub-sampling for each sheep.

Chemical analysis

Analyses of the chemical composition of the experimental feed ingredients and fecal samples were performed as outlined by A O A C (1995). Fecal samples for the chemical analysis were first oven dried at 60 °C for 48 h and milled using a cross-beater mill (Thomas Wiley, Philadelphia, USA) to pass through a 1-mm sieve and stored in plastic bags for a later chemical analysis. Ash was determined by combusting the samples at 550 °C for 5 h (A O A C , 2005). Total nitrogen (N) content was determined using a micro-Kjeldahl method. The crude protein (CP) content was then calculated from the N content adjusted by a conversion factor (N × 6.25). The acid detergent fibre (ADF) and neutral detergent fibre (NDF) contents were analyzed using the method of Van Soest et al. (1991) in an ANKOM 200 Fiber Analyzer (ANKOM Technology Corp., Fairport, USA). Both ADF and NDF were analyzed inclusive of residual ash and the latter was determined without heat stable amylase. All the samples were analyzed in duplicates at the Animal Nutrition Laboratory of Hawassa University.

Calculations and statistical analysis

The apparent digestibility and N retention were determined using the following formula:

Apparent digestibility = (nutrient consumed – nutrient excreted in feces)/(nutrient consumed) × 100

N-retention = N in feed consumed – (N excreted in feces + N excreted in urine) × 100

Data on nutrient intakes, live weight gain, nutrient digestibility and N retention were subjected to one-way ANOVA using SAS software (Statistical Analysis System, Version 9.4, 2012) by fitting treatment diets as a single fixed factor. When significant differences were observed among treatment means, they were separated by Duncan's Multiple Range Test. Comparisons with $P < 0.05$ were considered significant and all statements of statistical differences were based on this level unless noted otherwise.

The following linear model was used to analyze the data:

$Y_{ij} = \mu + T_i + e_{ij}$

where:

Y_{ij} = observed j^{th} variable in the i^{th} treatment diets (fixed factor)

μ = overall mean of the observed variable

T_i = effect due to i^{th} treatment diets (i = T1, T2, T3 and T4)

e_{ij} = random residual error

Table 1. Chemical composition of natural grass hay and sweet potato leaf

Contents ($g\ kg^{-1}$ dry matter)	Natural grass hay	Sweet potato leaf
Dry matter ($g\ kg^{-1}$)	922	918
Organic matter	889	953
Crude protein	37	265
Neutral detergent fibre	755	258
Acid detergent fibre	432	152

RESULTS

Feed intake

The CP content of SPL was high compared with that of natural grass hay. The NDF and ADF contents of SPL were low compared with that of natural grass hay (Table 1). The DM and nutrient intakes of sheep fed sweet potato leaves as a supplement to natural grass hay are presented in Table 2. The intake of DM, organic matter (OM) and ADF of hay was higher ($P < 0.001$) for the non-supplemented sheep than for the supplemented ones. Conversely, sheep supplemented with SPL had higher ($P < 0.001$) intakes of total DM, total OM and CP than those of non-supplemented. The DM intake of hay decreased ($P < 0.05$) with the increasing levels of SPL. On the other hand, the total DM, OM and CP intake increased ($P < 0.05$) with the increasing levels of SPL.

Growth performances

The supplemented sheep had higher ($P < 0.05$) average daily gain (ADG) than the non-supplemented group (Table 3). However, the differences in ADG observed among the supplemented groups were insignificant.

Table 2. Effect of sweet potato leaf supplementation on dry matter and nutrient intake of sheep on a basal diet of natural grass hay

Intake (g per head per day)	Levels of sweet potato leaf supplementation (g per head per day)				SEM
	0 (T1)	150 (T2)	300 (T3)	450 (T4)	
Dry matter intake					
Hay	415^{a}	387^{b}	325^{c}	221^{d}	15.5
Sweet potato leaf	–	138	276	415	80.0
Total	415^{d}	524^{c}	652^{b}	637^{a}	87.6
Organic matter intake					
Hay	370^{a}	343^{b}	293^{c}	201^{d}	13.4
Sweet potato leaf	–	131	262	397	76.7
Total	369^{d}	474^{c}	555^{b}	604^{a}	90.7
Crude protein	15.6^{d}	51.0^{c}	85.2^{b}	121^{a}	39.9
Neutral detergent fibre	303^{c}	318^{a}	316^{b}	258d	24.9
Acid detergent fibre	184^{a}	182^{b}	176^{c}	152^{d}	13.2

SEM = standard error of the mean

$^{a–d}$means with different superscripts within a row are significantly different

Table 3. Effect of sweet potato leaf supplementation on body weight change of sheep fed a basal diet of natural grass hay

Parameters	Levels of sweet potato leaf supplementation (g per head per day)				SEM
	0 (T1)	150 (T2)	300 (T3)	450 (T4)	
Initial body weight (kg)	18.1	18.0	19.3	18.5	0.30
Final body weight (kg)	18.4^{b}	21.8^{a}	23.0^{a}	23.2^{a}	0.59
Total weight gain (kg per head)	0.64^{b}	3.85^{a}	3.68^{a}	4.65^{a}	0.49
Average daily gain (g per head)	9.19^{b}	55.1^{a}	52.6^{a}	66.5^{a}	7.07

SEM = standard error of the mean

^{a,b}means with different superscripts within a row are significantly different

Table 4. Effect of sweet potato leaf supplementation on dry matter and nutrient digestibility in sheep on a basal diet of natural grass hay

Parameters	Levels of sweet potato leaf supplement (g per head per day)				SEM
	0 (T1)	150 (T2)	300 (T3)	450 (T4)	
Dry matter	68.0^{c}	83.2^{a}	80.3^{b}	80.1^{b}	1.28
Organic matter	72.4^{b}	84.6^{a}	83.0^{a}	83.4^{a}	1.12
Crude protein	–1.94^{c}	81.6^{b}	86.0^{ab}	89.1^{a}	8.02
Neutral detergent fibre	73.3^{bc}	83.5^{a}	75.8^{b}	70.8^{c}	1.07
Acid detergent fibre	73.0^{c}	82.9^{a}	75.9^{b}	70.8c	1.05

SEM = standard error of the mean

^{a,b}means with different superscripts within a row are significantly different

Digestibility of nutrients

Results on the nutrients digestibility in sheep fed a basal diet of natural grass supplemented with different levels of SPL are shown in Table 4. The digestibility of DM, OM and CP in the supplemented groups was higher ($P < 0.05$) than in the non-supplemented one. The CP digestibility in the non-supplemented group was negative. Among the supplemented sheep, the DM digestibility was the highest ($P < 0.05$) for sheep obtaining the T2 diet. The CP digestibility for sheep supplemented with T4 diet was higher ($P < 0.05$) than in the case of T1 and T2 diets while T3 had an intermediate value. The highest ($P < 0.05$) NDF and ADF digestibility values were observed for sheep supplemented with T2 diet.

Table 5. Nitrogen (N) retention (g per day) in sheep fed a basal diet of natural grass hay supplemented with different levels of sweet potato leaf

Parameters	Levels of sweet potato leaf supplementation (g per head per day)				SEM
	0 (T1)	150 (T2)	300 (T3)	450 (T4)	
N intake	1.86^{d}	7.64^{c}	13.2^{b}	19.2^{a}	1.33
Fecal N excreted	1.90^{a}	1.40^{b}	1.84^{a}	2.09^{a}	0.06
Urinary N excreted	2.66^{a}	1.66^{b}	1.59^{c}	1.50^{d}	0.09
N retention	–2.70^{d}	4.57^{c}	9.72^{b}	15.6^{a}	1.40

SEM = standard error of mean

$^{a–d}$means with different superscripts in the same row are significantly different

Nitrogen utilization

The N intake was higher ($P < 0.05$) in the supplemented groups than in the non-supplemented one and increased ($P < 0.05$) with the increasing levels of supplementation (Table 5). The lowest ($P < 0.05$) fecal N excretion was observed in sheep supplemented by T2 diet. No significant difference in fecal N excretion was observed among sheep fed T1, T3 and T4 diets. As shown in Table 5, the urine N excretion showed reduction ($P < 0.001$) with the increasing levels of SPL supplementation and differed ($P < 0.05$) across the treatment diets. The N retention increased ($P < 0.05$) with the increasing levels of SPL and it was negative for the non-supplemented group.

DISCUSSION

Effect of sweet potato leaf supplementation on growth

In some developing countries, sweet potato leaves and vines are used as animal feed, especially in feeding small stock like pigs, goats and sheep. The value of sweet potato is attributed to high yield, palatability and CP content, which make it a suitable protein supplement for animals receiving low quality forage. It has been shown that the leaves make up approximately half of the sweet potato vines biomass. However, to the authors' knowledge, there is little information available in the literature concerning the feeding potentials of SPL supplementation on the growth performance of sheep fed a basal diet of grass hay.

The intake of CP increased with the increasing levels of SPL supplementation to the basal diet of natural grass hay, which could be due to the increased consumption of the leaf. The results of CP intake in this study agreed with the report of Gebregiorgis et al. (2012) who reported similar findings for sheep supplemented with *M. stenopetala* leaves to Rhodes grass hay.

The increased CP intake with increasing levels of SPL supplementation may be due to the lower fibre contents and high CP content of SPL which possibly would increase the DM and CP intake of the rams. A study conducted by Foster et al. (2009) showed that supplementation of sheep fed a basal diet of grass hay with legumes improved the intake of DM, OM and CP, which is consistent with the current findings. On the other hand, the low total nutrient intake observed in the non-supplemented sheep could be due to the low level of CP in natural grass hay.

The similarity in weight gain among the supplemented sheep (as observed from the current study) is consistent with the reports of Yinnesu, Nurfeta (2012) in which SPL supplementation improved daily body weight gain, while feeding hay alone resulted in a loss of weight. According to Van Soest (1994) a minimum of 8% CP is required for optimum rumen function while grass hay used in the current experiment is below the optimum level. However, under small-scale production systems farmers feed whatever amount of SPL without considering how much the animals consume and how much they require. That is why the current study has been undertaken in an attempt to determine the optimum level of SPL supplementation, which can support a better response of sheep in terms of intake, weight gain, digestibility and N utilization. Lack of significant variation in daily live weight gain among the supplemented sheep may suggest that a high level of supplementation did not significantly affect weight gain.

The improved weight gain observed in the supplemented sheep could be due to the higher intake of CP as compared with the non-supplemented sheep which is in line with the findings of Gebregiorgis et al. (2012). The improved performance of sheep as a result of supplementation might be expressed in several ways such as by providing essential nutrients for rumen microorganisms, enhancing the microbial activities in the rumen, and providing nutrients. Melesse et al. (2018) reported 11.1 MJ kg^{-1} DM of metabolizable energy along with appreciable levels of volatile fatty acid (5.0 mmol kg^{-1} DM) contents for SPL indicating its potential to supplement energy to ruminants. The average daily weight gains of the sheep on supplemented diets were comparable to the result obtained by Katongole et al. (2009). The observed similarity in weight gain among different levels of SPL supplementation suggests that smallholder farmers can supplement low quality feeds with the low level of sweet potato leaves.

In the present study, the CP digestibility increased with the increasing levels of SPL supplementation. This is consistent with the findings of Gebregiorgis et al. (2012) that CP digestibility consistently increased with the rising levels of *M. stenopetala* leaf supplementation in sheep fed on Rhodes grass hay as a basal diet. Digestibility of CP generally increased as the CP intake increased because metabolic fecal N is inversely related to the CP intake and is higher at lower intake than at higher intake (Foster et al., 2009).

The digestibility of NDF and ADF was not consistent with increasing levels of SPL supplementation which is in good agreement with the findings of Sarwatt et al. (2002) who observed similar trends in the digestibility of nutrients with increasing levels of SPL as a substitute to sunflower seed cake in goats fed a basal diet of *Chloris gayana*. Generally, the advantage in N retention due to a specific ration is affected by several factors such as possible production of microbial protein synthesis, increasing presence of fermentable energy, differences in availability of fermentable energy (Holzer et al., 1986), variability in N that might escape fermentation from the rumen, an increased utilization of ammonia in the rumen and the effect of free fats in protein synthesis. The negative N balance observed in non-supplemented sheep could be due to a low voluntary feed intake and a low N content of natural grass hay. On the other hand, the observed increase in N retention in supplemented sheep might have resulted from the increased N intake and the increased CP digestibility. These observations agreed with those of Tolera, Sundstol (2000) registering a higher N retention in sheep fed a basal diet of maize stover supplemented with graded levels of *Desmodium intortum* hay. The rams on the basal diet of grass hay had an insufficient intake of CP resulting in a negative N retention and low body weight gain (Gebregiorgis et al., 2012). A negative N balance is an indicative of catabolism of body protein reserves to meet energy requirements (Robinson et al., 2005). On the other hand, Kaswari et al. (2007) suggested that losses of N in urine could mainly be caused by an oversupply of CP and/or an imbalance in the supply of amino acids. The positive N retention observed in all supplemented sheep indicated that the intake of N-containing compounds exceeds the loss of N from the body, and thus, such supplementation can meet the requirement of the sheep particularly during the drought season when most of feed resources became poor in quality. Therefore, the supplementation of SPL to hay-based diet could improve the efficiency of N utilization in the body of sheep. It is also worthwhile to note that recent *in vitro* studies conducted by Melesse et al. (2018) have indicated that SPL produces the least methane to net-gas production ratio among the studied leaves of root crops which suggests their additional potential in mitigating methane emission from the livestock agriculture of tropical countries.

CONCLUSION

The supplementation of SPL in sheep fed a basal diet of natural grass hay has resulted in improved intake, body weight gain, digestibility of nutrients and N retention. Thus, SPL can be used as a protein supplement to low-quality roughages under smallholder sheep production settings where conventional protein sources are beyond the reach of local farmers. Under the current experimental condition as little as 150 g of daily SPL is sufficient for optimal response. It is recommended that SPL could be used as an alternative supplement in a natural pasture hay-based feeding for sheep in places where sweet potato is grown in abundance.

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