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Full Length Research Paper

Performance and economic efficiency of browsing Arsi-Bale goats supplemented with sweet potato (*Ipomoea batatas L.*) vines as replacement for concentrate

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A total of forty Arsi-Bale male goats weighing on average (±SE) 16.8 ± 0.61 kg were used over a 132-day feeding period to determine the optimum level for substitution of concentrate with fresh sweet potato vines (SPV), having dry matter of 92%, crude protein of 19% and gross energy of 15.6 KJ/g DM for both biological and economic benefits. Five SPV substitution treatments in percentage: SPV0 as control, SPV25, SPV50, SPV75, and SPV100 were tested. The concentrate was a mixture of 78.4% wheat bran, 20.6% noug seed cake, and 1% salt with CP 20.5% and ME 2.16 MJ/kg DM. The animals took about 56 days to adapt to the SPV and recorded increasing DM intake with increasing inclusion of SPV in the ration. There were significant differences (*P* < 0.05) in body weight changes (ADG), body measurements and feed conversion ratio (FCR) that were lower after the recorded optimum 50% SPV substitution level. Economic analysis from the substitution treatments showed that SPV50 > SPV25 > SPV100 > SPV75 > SPV0, and 50% SPV substitution having most profitable with an average net return of 41.73 (ETB)/head. Therefore, it can be concluded that 50% SPV substitution for concentrate can be used for growing Arsi-Bale male goats with acceptable weight gain, feed intake, body measurements and economic returns.

Key words: Economic feasibility, feed conversion, feed intake, sweet potato vines.

INTRODUCTION

The starchy roots and tubers produced in many tropical areas constitute an important energy source for human consumption and feeding animals. Traditionally, sweet potato is cultivated almost exclusively for tuber production to be consumed by humans in the tropical countries of Latin America and the Caribbean while its foliage has always been considered as a residue. In Ethiopia, the crop is cultivated mostly in the highlands, though in recent times its cultivation is expanding to the lowlands also for tuber production while the green tops is rarely utilized as animal feed. However, Getachew et al. (2000) reported that sweet potato vines form one of the major feed resources for goats in the Harargahe highlands. The productive potentials of different varieties of sweet potato range from 3 to 4 ton DM/ha of root and the foliage production varies from 4.3 to 6.0 ton DM/ha/ crop (Ruiz et al., 1980).

Most developing countries are under increasing pressure to make more effective use of available resources in the agricultural sector both to satisfy the growing demands for livestock products and to raise rural incomes by generating value addition. The cost of balancing domestic demands for livestock products with feed or livestock imports has become prohibitively expensive. The prospects for increases in the output of cereals of the magnitude required to meet livestock feed both to spur domestic livestock production and to free cereal supplies for human consumption are receiving closer attention (Scott, 1992). The demand for additional feed sources, the identification and exploitation of traditional crops that are often grown with low inputs, and largely adapted to the climatic conditions of developing countries, would be a step towards better resource utilization (An, 2004). As a result, there is a rising interest in exploring the potentials for an expanded use of sweet potato as animal feed in developing countries Information about the utilization of sweet potato in developing

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Table 1. Chemical composition of experimental diets.

Feed type	DM (%)	CP (%)	NDF (%)	ADF (%)	ADL (%)	Ash (%)	GE (KJ/g DM)
Sweet potato vines	92.14	19.38	35.58	29.74	6.10	17.76	15.61
Wheat bran	92.46	17.01	52.17	17.25	-	7.64	20.35
Noug seed cake	95.73	35.5	32.01	28.16	-	9.02	21.36

countries is generally harder to come by and less reliable than is the case with other roots and tubers e.g. cassava and potato (Horton et al. 1984) . According to available statistics, about one third of sweet potato production in developing countries is used for animal feed on the farm itself (Scott, 1992). The crop is almost always used, in some form and amount, as animal feed as both the tubers and vines are used as feed or supplements for cattle, pigs, chickens and small ruminants wherever it is produced in developing countries (Karachi and Dzowela, 1988; Woolfe, 1992; Adugna et al., 2000). Unfortunately, information about the exact nature, extent and evolution of this practice is handicapped by a lack of knowledge about the crop generally and the use for animal feed specifically. Furthermore, specific information on supplementation of livestock diets with sweet potato vines is scanty in Ethiopia. Therefore, the current study was designed to evaluate the effect of substituting concentrate with sweet potato vines at increasing levels on feed intake, feed conversion ratio, economic efficiency and growth performance of Arsi-Bale goats.

MATERIALS AND METHODS

Experimental site

The study was conducted at Adami Tulu Agricultural Research Center, which is located 167 km South of Addis Ababa at an altitude of 1650 m above sea level in the mid-rift valley. The agro-ecological zone of the area is semi-arid and sub-humid with *Acacia* woodland vegetation type. The mean annual rainfall is 760 mm while the mean minimum and maximum temperatures are 12.6 and 27°C, respectively. The soil type is fine, sandy loam with sand:silt:clay in the ratio of 34:38:18, respectively, with a pH of 7.88 (ATARC, 1998).

Experimental animals and treatments

Forty yearling male Arsi -Bale goats were purchased from a local market. Arsi-Bale goat is identified as one of the distinct breed type both phenotypically and genetically. They are distributed throughout the Arsi, Bale and in the high altitude area of Sidamo and Western Hararghae zones. This breed type also predominantly exists in the mid rift valley of Ethiopia and is well adapted to the harsh environment and serves the community as sources of income, milk and meat (FARM- Africa, 1996). They are compact, medium in size and light in color. The purchased goats were treated for external and internal parasites with Accarcide and Albendazole, respectively. The experimental animals were, randomly, assigned to one of five sweet potato vines (SPV) substitution treatments based on their body weights and each treatment group contained eight animals. The treatments were: browsing **+** 0% SPV + 100% concentrate (T1=SPV0 as control), browsing + 25% SPV + 75% concentrate (T2=SPV25), browsing + 50% SPV + 50% concentrate (T3=SPV50), browsing + 75% SPV + 25% concentrate (T4=SPV75) and browsing + 100% SPV + 0% concentrate (T5=SPV100). However, two kids from SPV25 and SPV75 were died four weeks after the beginning of the experiment. A preliminary period of 14 days was given to allow adjustment of the growing animals to diets and facilities, and followed by 132 days of feeding period from June to October 2007. The supplemental feeds were weighed every morning and the animals fed 50% of their daily ration in the morning before they went for browsing and 50% in the afternoon upon their return from browsing/grazing. The ration was formulated based on the nutrient requirement of the animals where nutrients required for growth at 60g/day/head was considered while nutrient requirement for maintenance was assumed to be obtained form grazing/browsing. The supplement was given at a rate of 2.5% of their body weight.

Experimental feed and its composition

Feed type and its chemical compositions are given in Table 1. A local variety of sweet potato named Bellela was planted on the forage production experimental fields and all necessary agronomic practices such as land or seedbed preparation, planting, watering, and weeding were undertaken. This variety was selected for the study because it was the most promising both in tuber and biomass yields at either on- station or on-farm conditions in the mid-rift valley of Ethiopia. When the tuber matured (90 days after transplanting), the vines were harvested and chopped approximately into 5 cm length before serving to animals. The vines were harvested at equal days of interval to get vines of the same age. The concentrate supplement was a mixture of 78.4% wheat bran, 20.6% noug seed cake, and 1% salt with an estimated nutrient concentration of 20.5% CP and 2.16 MJ/ME per kg/DM. Refusals from each treatment group were collected, weighed and recorded daily in the morning to calculate intake before offering a fresh ration. Dry matter intake was calculated every 14 days by taking average daily intake within those days. Growth related parameters such as body weight and body measurements were also recorded every 14 days.

Economic return analysis was computed to examine the economic profitability of substituting concentrate with SPV. The costs of depreciation of barn and utensils as well as the value of dung were not included in the economic analysis because of unavailability of the data required for estimation. Moreover, sweet potato is cultivated in the area for the purpose of tuber production while the vines are wasted or left on the ground after tuber harvest. Few or no farmers properly utilize the vines as animal feed and there is no tradition of buying or selling the vines for animal feed and as a result, it is difficult to estimate the price of vines at specific units of measurement. Hence, the cost of sweet potato vines was not included in the economic analyses. The computation was done based on the average value of data obtained during the experiment. To examine the rate of return on annual bases, the annual financial rate of return (AFRR) to feeding was calculated using the formula (Baur et al., 1989):

$$AFRR = [(R-C)/C*(365/t)]*100\%$$

where; AFRR = Annual financial rate of return; R = revenue from

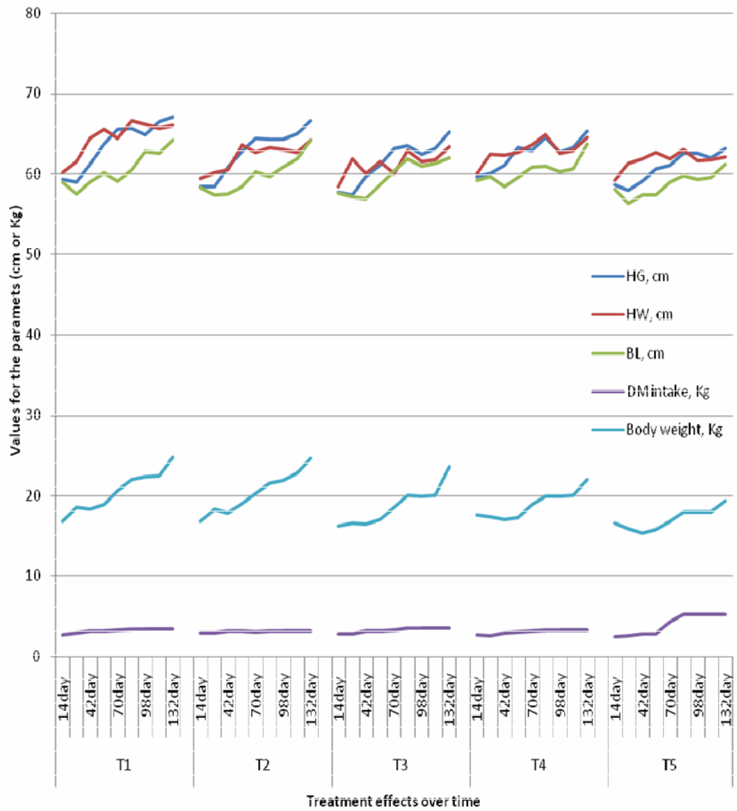

Figure 1. Trends in mean fortnightly DM intake, body weight and body measurements by Arsi-Bale goats fed increasing proportion of sweet potato vines as replacement for concentrate.

selling of the goat; C = purchase and other variable costs and; t= number of days the animal was fed. The AFRR to feeding is, thus, revenue less purchase cost of the animal and other variable costs, multiplied by the number of days in the year the animal was fed.

The return was decomposed into its compounds (price, weight and their interaction) to examine the relative contribution of the components in the gross return. All the components are expressed as percentages of the financial margin. To disaggregate the gross margin into its components the following formula was used:

$$100\% = \{(\Delta P^* W_i + \Delta W P_i + \Delta P^* \Delta W)/M\}^* 100\%$$

where; ΔP= the difference between sale price and purchase price; ΔW= the difference between final weight and initial weight at purchase; Pi = purchase price; Wi = initial weight at purchase

Sensitivity analysis was also done to capture the likely change in prices of input (feed) and fattened goat. Price variation can occur in input and output. Thus, these variations were considered in the sensitivity analysis.

Statistical analyses

Feed intake, body weight change and body measurement data were analyzed as a completely randomized design experiment using the General Linear Model procedures of SAS with diets as 5 treatments and animals as replications (SAS, 2000). Mean differences were considered significant at P<0.05 and mean separation among treatments was done using the Duncan's Multiple Range Tests. The model used was:

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

where; Y_{ij}= response variables such as average daily gain (ADG), DM intake, feed conversion ratio (FCR) and body measurements; μ= overall mean; T_i= effect of the ith dietary treatment; e_{ij}=random error associated with each observation.

RESULTS

Feed intake

"Average daily dry matter (DM) intake for Arsi-Bale goats fed different proportions of concentrate and sweet potato vines (SPV) are presented in Table 2. During the first 56 days of the experimental period, DM intake for SPV100 was significantly (*P* < 0.05) lower than other treatments whereas DM intake was highest (*P* < 0.05) for SPV100 followed by SPV50, SPV0, SPV75 and lowest for SPV25 starting from day 57 up to the end of the experiment (Figure 1). There was no significant (*P*>0.05) difference between the first three treatments in DM intake on days 42 and 56 while SPV75 had significantly (*P* < 0.05)

Table 2. Mean daily dry matter intake (kg/day), overall changes in body weight (ADG), feed conversion ratio (FCR), heart girth (HG), height at wither (HW) and body length (BL) by Arsi-Bale kids fed increasing proportions of sweet potato vines as replacement for concentrates.

Parameter	Treatment				
	T1	T2	T3	T4	T5
DM intake	3.2±0.03^{c}	3.0±0.04^{d}	3.2±0.02^{b}	3.0±0.05^{d}	4.0±0.06^{a}
ADG (g/day)	60.13±0.004^{a}	59.52±0.002^{a}	56.34±0.003^{a}	33.01±0.003^{b}	20.83±0.001^{c}
FCR	6.61^{d}	7.30^{c}	7.14^{c}	12.74^{b}	23.88^{a}
HG (cm)	63.99±0.61^{a}	63.07±1.02^{ab}	61.78±0.58^{b}	62.76±0.57^{ab}	60.89±0.67^{b}
HW (cm)	64.60±0.52 ^{a}	62.24±0.99 ^{ab}	61.38±1.11 ^{b}	62.96±0.78 ^{ab}	61.71±0.58 ^{b}
BL (cm)	60.83±0.72 ^{a}	60.17±0.63 ^{a}	59.8±0.78 ^{a}	60.67±0.83 ^{a}	58.89±0.54 ^{a}

Means in the same row with different letters are statistically significantly (P<0.05).

higher DM intake than SPV100 during the indicated period."

Trends in body weight change

The overall changes in body weight (ADG) and feed conversion ratio (FCR) for Arsi-Bale goats fed different proportions of concentrate and SPV are also presented in Table 2. On day 14 of the experimental period, the goats in SPV0 and SPV25 had significantly ($P<0.05$) higher body weight gain than other goats in the rest treatments and SPV50 had significantly ($P<0.05$) higher gain than SPV100 while there was no significant ($P>0.05$) difference among SPV75 and SPV100. However, there were a loss in weight in SPV75 and SPV100 which might be due to lower feed intake during the indicated period. Similarly, the goats in all treatments lost body weight on day 28, which might be due to the sudden outbreak of diseases that affected the flocks in the Center. However, goats in all treatments overcame the lost weight with higher gains in SPV25 by day 42 of the study period.
Weight gains in all treatments on days 56 and 70 were better ($P < 0.05$) than the preceding periods. However, body weight gain on day 84 and 98 were decreased ($P < 0.05$) as compared to weight gain on day 56, 70, 112, and 132 (Figure 1). The observed up and down trends in body weight gain were common for all treatments with significant ($P < 0.05$) differences at particular periods per treatment. Feed conversion ratio (FCR) for SPV75 and SPV100 was by far greater than the rest treatment groups which might be due to the expected lower digestibility or higher fiber in sweet potato vines than concentrate.

Linear body measurements

Mean heart girth (HG), height at withers (HW) and body length (BL) for Arsi-Bale goats fed different proportions of concentrate and sweet potato vines are also presented in Table 2. There were no significant differences ($P > 0.05$) in overall body length measurements among treatments while, higher significant ($P < 0.05$) variation were observed in overall heart girth and height at withers in SPV0 than SPV50 and SPV100. However in trend observation, there were no significant differences ($P > 0.05$) in heart girth measurements among treatments on the first 28 days. SPV0 and SPV25 had significantly ($P < 0.05$) higher heart girth than SPV100 starting from 43 days of experimental period up to the end of the experiment. There were no significant differences ($P > 0.05$) among treatments in height at withers and body length on the first 56 days while, SPV0 had significantly higher ($P < 0.05$) height at withers and body length than other treatments from day 57 to 98 of the experiment. SPV0 had also significantly ($P < 0.05$) higher height at withers and body length than SPV100 on days 112 and 132 of the experimental period, respectively (Figure 1). Generally, linear body measurements decreased as the proportion of sweet potato vines in the ration increased which is similar to body weight changes obtained in the experiment.

Economical analyses

The results of economic analyses carried out on the rations are shown in Table 3. Even though the analysis revealed that feeding goats using all feed options in the trial was profitable, there was a defined trend with SPV50 > SPV25 > SPV100 > SPV75 > SPV0, in that order. One way farmers might increase profitability is by reducing feeding costs per animal. Therefore, reducing the amount of concentrate in the ration which represents about 40% of the total operating cost and 64% for SPV25 could result in profit making.

Different components of the gross margin

The results from the gross margin analysis when described as percentages of financial return also indicates that weight gain, as a whole, accounted for 52% of the gross margin while price changes and the interactions accounted for 36 and 12%, respectively

Table 3. Cost and economic return analysis (per animal) for Arsi-Bale goats fed increasing proportion of sweet potato vines (SPV) as replacement for concentrate.

Item	Treatment				
	T_1	T_2	T_3	T_4	T_5
Number of animals per treatment	8	7	8	7	8
Average purchase price (ETB**) per kg	6.75	6.75	6.75	6.75	6.75
Average live weight (kg) @purchase per head	16.81	16.79	16.19	17.57	16.56
Average purchase price (ETB) per head	113.47	113.33	109.28	118.6	111.78
Operating costs (per head)					
I. Feed (concentrate)	48.94	39.67	24.63	13.21	0.00
II. Labor	18.19	20.79	18.19	20.79	18.19
III. Medicine	1.12	1.12	1.12	1.12	1.12
Total operating costs (per head)	68.25	61.58	43.94	35.12	19.31
Average total cost per head(ETB)	181.72	174.91	153.22	153.72	131.09
Average live weight (kg)@sale per head	24.75	24.64	23.63	21.93	19.31
Total body weight gain in kg per head	7.94	7.86	7.44	4.36	2.75
Average selling price per kg of live weight (ETB)	8.25	8.25	8.25	8.25	8.25
Average return (gross return)/head(ETB)	204.19	203.28	194.95	180.92	159.31
Average net return (NR0)(ETB)	22.47	28.37	41.73	27.21	28.22
Annual financial rate of return (AFRR)(ETB)	50.15	65.77	110.44	71.78	87.30

**ETB = Ethiopian Birr; 9.5 ETB = 1 US Dollar.

(Table 4). This suggests that weight gains over the feeding periods relatively played an important role in the determination of profitability.

Sensitivity analysis

In Ethiopia the price recorded for the commodities in general and animal feed in particular for the last five years have shown dramatic increment while little or less price fall was recorded (CSA, 2008). The average price computed for increments and decrease of the commodities using the time series data for the last five years suggested that it is rational to hypothesize 20% increase in concentrate and 10% decrease in selling price of goat. Thus, sensitivity analysis was hypothesized for 20% increase in concentrate and 10% decrease in selling price of goat in order to capture the likely change of price of input and fattened goat. For example, in the year 2007/2008 more than 100% increment in commercially produced feed was recorded. Based on this fact, price variations were considered in the sensitivity analysis. In agricultural production, decrease or increases in input and output price have great impact on farmers' return. Apart from purchase price which constituted about 72% of the total production cost, feeding was the most expensive commodity ranging from 8% to 27%. A 20% increase in concentrate feed price would decrease the return per head by 44%, 28%, 11.8% and 9.75% for SPV0, SPV25, SPV50, SPV75, and SPV100, respectively. The result indicates that it is better for the farmers to reduce the utilization of concentrate in the ration and look for cheaper feed sources that could substitute, commercially, produced feeds. Accordingly the use of sweet potato vine is vital in this case to fetch good profit.

A 10% decrease in selling price of fattened goat will reduce net return in ETB/head by 91%, 71.7%, 46.72%, 66.5% and 56.46% for SPV0, SPV25, SPV50, SPV75, and SPV100, respectively (Table 5). Relatively speaking, the analysis indicated that feeding the goats was highly affected by changes in selling price of fattened goats especially for those fed SPV0 and SPV25 compared to other treatments since purchase price accounts for more than 72% of the total cost of production.

DISCUSSION

Initially, DM intake was reduced as the level of sweet potato vine inclusion in the ration increased; but 56 days later, the intake was increased linearly as the amount of SPV in the ration increased which might be due to the familiarity of experimental animals with the feed. This indicated that sweet potato vine supplementation could not affect DM intake negatively rather, it enhanced intake once the animal have adapted to the feed. Lam and Ledin (2004) reported that DM intake decreased linearly as *Sesbania* foliage was replaced by SPV, which was not in agreement with the present report and might be due to

Table 4. Different components of the gross margin.

Treatment	Component of gross margin (%)			Weight gain overprice (folds)
	Price	Weight	Interaction	
T_1	27.79	59.08	13.13	2.13
T_2	28.00	58.98	13.11	2.11
T_3	28.35	58.62	13.03	2.07
T_4	42.29	47.22	10.49	1.12
T_5	52.26	39.06	8.68	0.75
Average	35.74	52.59	11.69	1.64

Table 5. Sensitivity analysis of net return for 20% increase in feed price and 10% decrease in selling price of fattened goats.

Variable	T1	T2	T3	T4	T5
Initial net return(NR_0) (ETB)	22.47	28.37	41.73	27.21	28.22
NR_1 (ETB)	12.7	20.44	36.8	24.56	28.22
NR_2 (ETB)	2.05	8.04	22.23	9.11	12.29
NR_1 (ETB)	44	28	11.8	9.75	0
NR_2 (ETB)	91	71.7	46.72	66.5	56.46
% of feed cost over total cost of production	26.93	22.68	16.07	8.59	0.00
% of purchase price over total cost of production	62	65	71.3	77.2	85.3

NR_0: Initial net return without an increase in feed price and a decrease in selling price; NR_1: Net return with 20% increase in feed price without a change in selling price; NR_2: Net return with 10% decrease in selling price without changes in feed price; NR_1 (%): percentage change in net return with 20% increase in concentrate without a change in selling price; NR_2 (%): percentage change in net return with 10% decrease in selling price without a change in feed price.

the difference in type of feed replaced by SPV. Also, Netsanet (2006) reported a decrease in overall DM intake as the level of sweet potato vines increased in feeding goats. In support of the present study, Dominguez (1992) reported that supplementation of sweet potato forages improved feed intake of young bulls fed a basal diet of sugar cane stalks.

The trends observed in overall ADG that is, SPV0=SPV25=SPV50>SPV75>SPV100 implies that sweet potato vines could replace concentrates, at least, up to 50% in the ration of yearling Arsi-Bale male goats. Similarly, Lam and Ledin (2004) reported that fresh sweet potato vines can replace 50% of *Sesbania grandiflora* with acceptable live weight gains of 60.9 g/day. Netsanet (2006) observed the absence of significant differences in weight gain among 25 and 50% sweet potato vine level of substitution for concentrate but, growth performance observed in previous studies was inferior than the present study which might be attributed to the differences in proportion and type of concentrate replaced and in the type of feeding system (indoor feeding vs. browsing plus supplementation, respectively). Semenye and Hutchcroft (1992) working with dual purpose goats found that sweet potato vines met the requirements of kids when fed 30 gm DM per kg of body weight per day. The findings from the present study agreed with a previous study where Borana weaner calves fed a basal diet of Rhodes grass hay and supplemented with 500 g/head/day of sweet potato vines resulted in a growth rate equivalent to that of calves fed 200 g cotton seed cake/head/day (Karachi and Dzowela, 1988). The performance of goats fed sweet potato vines at higher levels was less satisfactory compared to concentrates suggesting that for the vines, 50% replacement of the concentrate is advisable. Even though growth rate declined as concentrate was replaced by sweet potato vines, there were improvements in weight gain (Table 2) since weight gain in Arsi-Bale goats kept on grazing/browsing alone was not more than 7.94 g/day (Mieso et al., 2004).

Feed conversion of replacing concentrate with sweet potato vines showed that performance declined with increasing levels of concentrate replacement with sweet potato vines. A similar result was reported by Lam and Ledin (2004) who replaced *Sesbania grandiflora* with sweet potato vines in the ration of crossbred goats (Bach Thao × Local female). Mixing of sweet potato forage and root in equal proportions resulted in improved nutrient utilization (Olorunnisomo, 2007).

Performance in linear body measurements mirrored the performance in body weight change. Literatures are hardly available on linear body measurements for Arsi-Bale goat breed in feed substitution type-study. As a result, studies on this breed with different types of feeding were reviewed. Tesfaye et al. (2008) reported 79.67±0.82; 76.56±0.87 and 77.67±0.87 cm of heart girth, height at wither and body length respectively for intact male Arsi-Bale goats at eighteen months of age. These values were by far higher than the present study's which could be due to long period exposure to concentrate feed in previous studies. The present study agreed with the report of Nsoso et al. (2004) who worked on Tswana goats.

Mengistu et al. (2006) reported that similar economic trend on cattle fattening practice of smallholder farmers were economically evaluated under different systems. Their findings indicated the importance of formulating cheap feed source that can substitute expensive industrial by-products indicating the fact that feed cost constitutes the lion's share of total variable cost which is an indication that the use of sweet potato vine as a potential feed resource is economical. Another study in the South-West of Nigeria by Olorunnisomo (2007) showed that mixing sweet potato forage and root in equal proportions reduced the cost of live weight gain and maximized economic returns from sweet potato cultivation for sheep.

CONCLUSION AND RECOMMENDATION

The study indicated that increased substitution of concentrate with fresh sweet potato vines in the ration resulted to increments in DM intake. There was a tendency for reduction in the rate of weight gain as the proportion of sweet potato vines increased in the ration. The average daily gain showed that up to 50% concentrate substitution with sweet potato vines was similar to the 100% concentrate control diet, which implies that 50% replacement of concentrate with fresh sweet potato vines in the ration of growing Arsi-Bale goats resulted in acceptable live weight gain, feed intake and economic returns. There was a clear trend in the recorded profitability with SPV50 > SPV25 > SPV100 > SPV75 > SPV0, in that order. Thus, fresh sweet potato vines could be used as supplemental feed for goats where the crop is grown. Furthermore, to fully ascertain the potential of sweet potato vines as alternative supplemental feeds for goat, future studies should be carried out in the dry period when the goats will be exposed to very minimal alternative browse as feed.

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