Sweet potato as a ruminant feed: Performance of sheep fed mixtures of the forage and root.

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Abstract

Scarcity of quality forage during the dry season poses a serious problem to ruminant production in southwest Nigeria. Dried sweet potato (SP) vine and root have the potential to bridge the gap in feed supply for ruminants during this period. In a feeding trial, fifteen male West African dwarf (WAD) sheep were used to estimate the nutritive value of SP forage and root as a basal feed for ruminants during the dry season. Experimental diets consisted of SP forage and root in the following proportions, 0:100, 25:75, 50:50, 75:25, and 100:0 (forage: root). In the first part of the trial, growing WAD sheep were fed experimental diets for twenty weeks. Dry matter (DM) intake and growth rate of the animals were measured. In the second part, digestibility and nitrogen balance of sheep fed the experimental diets were measured. Intake, growth rate, digestibility and nitrogen retention improved significantly ($P < 0.05$) when SP forage and root were mixed in the diet. The DM intake ranged from 1.8 to 4.9 % body weight; growth rate, -34.1 to 86.43 g/day; DM digestibility, 64.6 to 70.4%; and nitrogen retained, 29.5 to 51.0%. Performance, digestibility and nitrogen utilization of WAD sheep was highest when SP forage and root formed equal proportions (50:50) in the diet. Mixing SP forage and root in the diet proved beneficial to growing sheep and equal proportions of the forage and root in the diet appear to be the most appropriate combination.

Keywords: Sweet potato, Sheep, Intake, Growth, Digestibility, Nitrogen Balance

Introduction

Inadequate supply of quality forage on a year round basis is a major problem to the productivity of ruminants in the southwest of Nigeria. Yield and quality of forage from perennial tropical grasses decline rapidly toward the dry season, leading to a shortage in supply of quality feed during this period. Under improved cultivation, sweet potato is capable of producing a very high dry matter yield per unit area of land. Yields of 22 t/ha of forage and 11 t/ha of roots have been reported (Rashid *et al.*, 2000; Moat and Dryden, 1993). The vine is rich in protein while the root is rich in energy (An *et al.*, 2003). Digestibility of sweet potato forage and roots for pigs has been reported by Giang *et al.* (2004) to be very high. *In vitro* digestibility of sweet potato forage and

roots has also been reported by Backer *et al.* (1980) to be high. There is however, a paucity of information on the *in vivo* digestibility of this fodder crop for ruminants.

The chemical composition and high yield of sweet potato makes it a crop of great potential for feeding ruminants during periods of feed scarcity in Nigeria. Sweet potato vines have been fed to ruminants as forage while the root has formed part of the concentrate diet (Lam and Ledin, 2004; Tewe *et al.*, 1982). There is however, little information on the value of the whole plant (forage and root) as a meal for ruminant animals in Nigeria.

Performance of WAD sheep fed sweet potato forage and roots

In tropical America, a feeding system for ruminants based on the use of crop residues and whole crop biomass has been developed for the smallholder farmer (Ruiz, 1982). A similar system based on the whole crop of sweet potato may also be developed for feeding ruminant stock in Nigeria during the dry season. The use of sweet potato forage and root as a ruminant feed is expected to yield a better economic return in terms of land use efficiency and animal production.

This study reports the intake, weight gain, feed conversion ratio, digestibility and nitrogen balance of West African dwarf sheep fed different combinations of sweet potato forage and root in the total diet.

Materials and Methods

This study was conducted in two parts. The first part corresponds to the growth trial where intake, growth rate and feed conversion ratio of the animals were measured. The second part corresponds to the metabolic trial where digestibility and nitrogen balance of the animals were measured.

Feed Preparation

The sweet potato forage and root used in this experiment were collected from a field at the University of Ibadan. Fresh forages and roots were chopped using a fabricated machine. The chopped materials were sun dried on polythene sheets for 5-6 days. The dried sweet potato forage and roots were ground into a meal using a hammer mill and mixed in the following proportions; 0:100, 25:75, 50:50, 75:25 and 100:0 (forage: root). Salt, vitamin-mineral premix and oyster shell meal were each added to the mixtures at the rate of 0.5 percent. The mixtures were pelleted and stored for the feeding trial. The ingredient composition of the experimental diets is shown in Table 1.

Growth Trial

Fifteen male West African dwarf lambs approximately six months old with mean weight 8.3 ± 1.7 kg were housed in separate pens with feeding and watering troughs. The animals were divided into three groups according to their weights and randomly assigned to one of five diets, containing sweet potato forage and root in the proportions specified above. The animals were treated with *Ivomectin* and *Gamatox* to take care of internal and external parasites. Animals were also treated with antibiotics before the commencement of the trial. Feed was offered *ad-libitum* at 105% of previous day's intake once daily at 8.00 hours. Fresh water was offered free choice on a daily basis. The animals were offered the experimental diets for 150 days. Ten days were allowed for adaptation to the pens and diets while experimental measurements were taken in the last 140 days. Feed offered and feed refused were recorded for each animal daily while animal weights were taken on a weekly basis, using a spring balance. Average daily intake (ADI) and average daily gain (ADG) were calculated for each animal over the 140-day period. Feed conversion ratio was also calculated for each treatment from ADI and ADG.

Metabolic Trial

At the end of the growth trial, slatted wooden platforms adapted for faecal and urine collection was introduced into the animal pens. Experimental diets were offered *ad-libitum* on a daily basis for 14 days. Total faeces, urine and feed refused were collected and weighed in the last 7 days. Feed intake, faecal output and urinary output were determined. Ten per cent of faeces and urine collected were taken for analysis. Feed and faecal samples were dried at 65°C to constant weight, milled and kept in airtight containers while urine samples were kept in a deep freezer at -5°C until required for analysis. Apparent

Table 1. Ingredient composition of experimental diets.

Ingredient	Diets (forage: root)				
	0:100	25:75	50:50	75:25	100:0
Sweet potato forage	0.0	24.6	49.2	73.9	98.5
Sweet potato root	98.5	73.9	49.3	24.6	0.0
Salt	0.5	0.5	0.5	0.5	0.5
Vitamin-mineral premix	0.5	0.5	0.5	0.5	0.5
Oyster shell	0.5	0.5	0.5	0.5	0.5
Total	100.0	100.0	100.0	100.0	100.0

digestibility of the diets was calculated as the difference between nutrient intake and excretion in the faeces, expressed as a percentage of nutrient intake using the following equation:

$$D_x = \frac{(F_o \times A_o) - (F_i \times A_i)}{(F_o \times A_o)} \times \frac{100}{1}$$

Where D_x = digestibility coefficient of nutrient

F_o = quantity of feed consumed in grammes (DM)

A_o = percent nutrient content in feed (DM)

F_i = quantity of faeces voided in grammes (DM)

A_i = percent nutrient content in faeces (DM).

Nitrogen retained by the animals was calculated as the difference between nitrogen intake and nitrogen excreted as follows:

$$N_{\text{retained}} = N_{\text{intake}} - (\text{Faecal N} + \text{Urinary N})$$

In this trial, the 100% sweet potato root (0:100) diet was sprayed with a 10% urea solution to raise the crude protein content to 8.85%. This was done to avoid the incidence of low DM intake experienced by animals on this diet during the growth trial.

Chemical Analysis and Experimental Design

Nitrogen content of feed, faeces and urine were determined by the Kjeldahl method (AOAC, 1995) while proximate composition, detergent fibre and gross energy content of the feed and faeces were determined by the methods of AOAC (1995), Van Soest and Robertson (1985) and Nehring and Haenlein (1973) respectively.

The experimental design adopted for both trials was the randomized complete block design. Data obtained were subjected to analysis of variance and significant means were separated by Duncan's multiple range tests using the SAS (1995) procedures.

Results and Discussion

The chemical composition of the experimental diets is given in Table 2. The energy level in the diets are similar while crude protein and fibre components of the diets increased with increasing level of sweet potato forage in the diets. This is explained by the higher levels of protein and fibre in sweet potato forage compared to the root.

The dry matter intake, growth rate and feed conversion ratio of sheep fed the various

Performance of WAD sheep fed sweet potato forage and roots

Table 2. Chemical composition (g/100g DM) and energy (kcal/g) of sweet potato based diets

Components	0:100 ^a	25:75	50:50	75:25	100:0
Dry matter	93.80	93.20	92.60	92.40	91.60
Crude protein	4.85	9.05	12.65	16.28	20.05
Ether extract	1.15	1.86	2.55	3.15	3.85
Crude fibre	3.26	8.38	12.25	15.87	19.65
Ash	4.06	5.54	7.15	8.85	10.24
Nitrogen free extract	86.68	75.17	65.40	55.85	46.21
Neutral detergent fibre	9.24	18.25	28.20	36.05	45.06
Acid detergent fibre	4.00	10.35	16.45	22.50	28.00
Lignin	0.38	0.82	2.25	3.74	4.20
Gross energy	4.09	4.15	4.21	4.27	4.23

* During the metabolic trial this diet was sprayed with a 10% urea solution to increase the nitrogen content hence the composition was altered as follows; DM: 92.65, CP: 8.85, EE: 1.14, CF: 3.25, Ash: 4.00, NFE: 82.76, NDF: 9.24, ADF: 4.00, Lignin: 0.35 g/100g DM; GE: 4.10 kcal/g. This was done to avoid the incidence of low DM intake experienced by animals on this diet during the growth trial.

Table 3. Dry matter intake, growth rate and feed conversion ratio of WAD sheep fed sweet potato forage and root

Parameter	Diets (forage: root ratio)					SEM
	0:100	25:75	50:50	75:25	100:0	
No. of animals	3.00	3.00	3.00	3.00	3.00	-
Initial weight, kg	8.43	8.17	8.37	8.20	8.30	0.25
Final weight, kg	7.46	18.10	20.50	19.13	16.30	0.83
ADG, g/day	-34.13 ^e	70.95 ^c	86.43 ^a	78.10 ^b	56.91 ^d	2.71
ADI, g/day	83.60 ^d	626.44 ^b	657.73 ^a	627.32 ^b	595.82 ^c	7.51
ADI, % BW	1.80 ^b	4.81 ^a	4.67 ^a	4.57 ^a	4.98 ^a	0.28
ADI, g/kg ^{0.75}	26.28 ^b	91.45 ^a	90.50 ^a	87.98 ^a	92.66 ^a	3.56
FCR	-2.44 ^d	8.84 ^b	7.62 ^c	8.03 ^c	10.48 ^a	0.30

^{a, b, c, d, e} Means with same superscript within the row are not significantly different (P > 0.05)

ADI: average daily intake, DM

ADG: average daily gain

FCR: feed conversion ratio (intake/gain)

BW: body weight

W^{0.75}: metabolic weight

mixtures of sweet potato forage and roots are presented in Table 3.

Dry Matter Intake

Animals on the 100% sweet potato root (0:100) diet lost weight, scoured persistently and stopped eating by the 4th week. This is thought to be due to the low level of protein (4.9% CP) and fibre (3.3% CF), which caused a digestive disorder in the rumen. The protein content of this diet (100% roots) is below the 6-7% minimum level recommended for ruminant diets by Milford and Haydock (1965).

There were significant differences ($P < 0.05$) in the dry matter intake from the diets on percent body weight or metabolic weight basis. This was due mainly to the low DM intake experienced by animals on 100% root diet. It is of note that DM intake from other diets was high and similar, suggesting that the nitrogen content of these diets were adequate for microbial activity in the rumen. The DM intake obtained in this study were 1.8, 4.8, 4.7, 4.6, and 4.9% of body weight (BW) for Diets I, II, III, IV and V respectively. These values were broadly higher than the range of 3.3 – 3.8 % BW obtained by Olorunnisomo and Ososanya (2002) for WAD goats fed maize offal and sorghum brewer's grains in a total diet. Backer *et al.* (1980) reported a mean DM intake of 2.37% BW for cattle fed different mixtures of sweet potato forage and root. When expressed on metabolic weight basis, DM intake in this study were 26.3, 91.5, 90.5, 88.0, and 92.7 g/kg $W^{0.75}$ for the respective diets. These were higher than the mean DM intake of 43.6g/kg $W^{0.75}$ obtained by Olubajo and Aken'ova (1985) for sheep fed a sole diet of elephant grass, and 71 g/kg $W^{0.75}$ reported by Peyraud and Astigarraga (1998) for sheep fed different grass forages. The high DM intake observed in sweet potato based diets may have resulted from the high

degradation rate in the rumen and consequently a faster rate of digesta passage through the gut.

Growth Rate

The growth rate (average daily gain) of sheep differed significantly ($P < 0.05$) among the treatments. Animals fed equal proportions of sweet potato forage and root (50:50) showed the highest weight gain, followed by 75% forage (75:25), 25% forage (25:75) and 100% forage (100:0) respectively. Animals on 100% root (0:100) had a negative weight change (-34.13 g/day). This might be a result of the low DM intake and digestive disorders induced by the low nitrogen concentration and low fibre content of the diet. High concentrate or low-fibre diets are known to cause feedlot bloat (excessive accumulation of gases in the rumen) in stall-fed ruminants (McDonald *et al.*, 1987). Growth rate increased with increasing level of sweet potato forage in the diet up to 50% and then declined. The mean growth rates in this study were -34.13, 70.9, 86.4, 78.1, and 56.9 g/day for 0:100, 25:75, 50:50, 75:25 and 100:0 respectively. These values are generally higher than the 44.2 - 63.5 g/day obtained by Lam and Ledin (2004) for goats fed sweet potato vines and *Sesbania grandiflora* forage, and the 11.9 - 67.9 g/day obtained by Adeneye and Sunmonu (1994) for WAD sheep fed grass-legume forage with concentrates.

Feed Conversion Ratio

The feed conversion ratio of WAD sheep fed the different diets is given in Table 3. There were significant differences ($P < 0.05$) among the treatments in feed conversion ratio. When the diet consisted of sweet potato forage (100:0) or root (0:100) alone, FCR was high or negative, showing that feed was not efficiently converted by the animals. However, when the forage and root were mixed in the diet, FCR was lower, indicating a more efficient feed conversion. Animals on the 50:50 diets showed the best feed

conversion followed by 75:25 and 25:75 respectively. This is largely a reflection of the weight gain by the animals from the various diets. The feed conversion ratio for animals on 100% root diet was negative due to the negative weight change experienced by these animals. The difference between the feed conversion ratio of diets 50:50 and 75:25 was not significant ($P>0.05$), showing that the conversion efficiency of these diets were similar. The feed conversion ratio obtained in this study were -2.44, 8.84, 7.62, 8.03, 10.48 for sheep fed 0:100, 25:75, 50:50, 75:25 and 100:0 combinations of sweet potato forage and roots respectively. Apart from the 0:100 diet, mixtures of sweet potato forage and roots appear to be better converted to meat by small ruminants than elephant grass supplemented with cassava peels and palm kernel cake (Fasae *et al.*, 2007) or pigeon pea-based diets (Arigbede *et al.*, 2005). Abubakar *et al.* (2005) however reported a superior feed conversion ratio (5.38 - 7.35) for goats fed complete diets based on groundnut haulms and cowpea shell.

Digestibility

The apparent digestibility of the various dietary combinations is given in Table 4. Results show there were significant differences ($P<0.05$) in DM, CP, NDF and ADF digestibility of the diets. The diet with 100% sweet potato root (0:100) had the least DM and CP digestibility while the 50:50 diet had the highest. Dry matter digestibility tended to improve with the inclusion of sweet potato forage in the diet. When sweet potato forage and root were mixed together in the diet, protein-energy ratio and fibre content of the diet increased. This was probably responsible for the observed improvement in DM digestibility when sweet potato forage formed part of the diet. Digestion in ruminant animals is highly influenced by the level of protein and fibre in the diet. A low protein concentration in the diet

reduces microbial synthesis and consequently, intake and digestibility of the diet is reduced (Olorunnisomo *et al.*, 2006; McDonald *et al.*, 1987). The quantity and nature of dietary fibre also influences microbial synthesis in the rumen. A good fibre mat must be maintained in the rumen to ensure adequate growth and activity of rumen microbes (Ishler *et al.*, 1996). Diets with very low fibre contents can result in digestive disorders such as scours and feedlot bloat in ruminants. At equal proportions of sweet potato forage and root in the diet, protein-energy ratio was probably at the optimum level, thus providing an optimal condition for microbial synthesis in the rumen and DM digestibility of the diet.

The NDF and ADF followed a similar trend with DM digestibility with the 100% sweet potato root diet having the least values and diets containing sweet potato forage, higher values. Digestibility of fibre tended to improve with increasing levels of sweet potato forage in the diets. This is a reflection of the higher protein level in sweet potato forage relative to the root. This result agrees with other reports that increased level of protein in ruminant diets improved the digestibility of such diets (Olorunnisomo *et al.*, 2006; Olorunnisomo and Ososanya, 2002; Peyraud and Astigarraga, 1998; McDonald *et al.*, 1987; Ffoulkes *et al.*, 1978).

Nitrogen balance

The utilization of nitrogen in the diets by WAD sheep is presented in Table 5. Results show that nitrogen intake from the diets and nitrogen loss in faeces increased with increasing level of sweet potato forage in the diets. This was a reflection of the higher protein level in the forage compared to the root. Increased nitrogen loss in faeces is associated with higher protein intake by animals and higher protein concentration in the diet (Tolera and Sundstol, 2000; Chowdhury, 1997;

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Table 4. Apparent digestibility (%) of sun dried sweet potato forage and root by WAD sheep

Components (%)	Diets (forage: root ratios)					SEM
	0:100	25:75	50:50	75:25	100:0	
Feed intake (g/day, DM)	555.97	631.67	673.73	638.35	591.91	7.85
Faecal output (g/day, DM)	196.86	209.76	199.65	203.20	190.96	5.03
Dry matter	64.60 ^b	66.79 ^{ab}	70.42 ^a	68.25 ^a	67.78 ^a	4.90
Crude protein	55.76 ^b	60.19 ^{ab}	65.74 ^a	64.34 ^a	64.72 ^a	2.32
Neutral detergent fibre	50.35 ^b	52.68 ^b	63.28 ^a	60.53 ^a	64.24 ^a	2.45
Acid detergent fibre	40.35 ^c	49.23 ^b	59.35 ^a	57.52 ^a	59.72 ^a	2.81

^{a, b, c} Means with same superscripts within the row are not significantly different ($P > 0.05$).

Table 5. Nitrogen balance of WAD sheep fed sun dried sweet potato forage and root

Measurement (g/day)	Diets (forage: root ratios)					SEM
	0:100	25:75	50:50	75:25	100:0	
^a						
Feed intake (DM)	555.97	631.67	673.73	638.35	591.91	7.85
% N in feed	1.41	1.45	2.02	2.60	3.21	-
Faecal output (DM)	196.86	209.76	199.65	203.20	190.96	5.03
% N in faeces	1.77	1.74	2.34	2.93	3.51	-
Urinary output	160.00	193.81	190.48	193.81	193.81	4.97
% N in urine	1.30	1.12	1.05	1.19	1.54	-
N intake	7.87	9.15	13.64	16.63	18.99	0.56
Faecal N	3.48	3.64	4.68	5.94	6.70	0.29
Urinary N	2.07	2.17	1.99	2.29	2.98	0.09
N retained	2.32	3.34	6.96	8.40	9.31	0.30
% N absorbed	55.77 ^b	60.19 ^{ab}	65.74 ^a	64.39 ^a	64.75 ^a	2.05
% N retained	29.48 ^b	36.50 ^{ab}	51.03 ^a	50.51 ^a	49.03 ^a	1.78

^{a, b} Means with same superscripts within the row and not significantly different ($P > 0.05$)

Bonsi *et al.* 1994). Nitrogen loss in the urine however did not follow a clearly defined pattern, with the 50:50 diets showing the least urinary N loss and the 100:0 diets, the highest. Total nitrogen retained increased with increasing levels of sweet potato forage in the diets. When expressed as a percentage of N intake, N retained differed significantly ($P < 0.05$) among the diets. Animals on the 50:50 diets had the highest N

retention while animals on 0:100 diets had the least. Nitrogen utilization by WAD sheep improved significantly ($P < 0.05$) when sweet potato forage formed part or all of the diet. There was an improvement of 24 and 73% in N utilization when the forage formed 25 and 50% of the diet respectively; however, beyond the 50% inclusion level, there was no significant difference ($P > 0.05$) in N retention among the experimental animals.

This suggests that protein was better utilized when sweet potato forage and root were mixed in equal proportions in sheep diets.

Results from this study is consistent with the findings of Tolera and Sundstol (2000) and Bonsi *et al.* (1994) who reported an increase in N intake, faecal output and N retention with increasing level of protein in the total diet. The N retained as a percentage of N intake by sheep ranged from 29.5 - 51.0% in this study. These values were lower than the 55.5 - 60.8% nitrogen retention obtained by Tewe *et al.* (1982) for lambs fed grass and concentrate diets but slightly higher than the 24.5 - 47.4% obtained by Adeneye and Sunmonu (1994) for sheep fed grass-legume forage with concentrates. Nitrogen absorbed followed a similar trend with N retention.

Conclusion

The intake, growth rate and feed conversion ratio of growing West African dwarf sheep improved when sweet potato forage and root were mixed in the diet. Digestibility and nitrogen utilization also improved with mixtures of the forage and root in the diet. Animal performance, digestibility and nitrogen utilization was highest when sweet potato forage and root formed equal proportions (50:50) in the diet. This suggests that optimum protein-energy ratio for microbial synthesis was achieved at this dietary combination of the forage and root. When the whole crop forms the basis for feeding ruminants, an equal proportion of the forage and root is recommended in the diet.

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