Studies on sweet potato forage and dried brewers' grains as supplements to green panic for Bunaji cows

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Abstract

Growth of sweet potato (*Ipomoea batatas*) was examined in a plot study. Forage yield and leaf: stem ratio decreased (P<0.05), while harvest index (tuber yield:tuber+forage yield) increased, as harvesting was delayed from 12 to 20 weeks after planting (WAP). Tuber yields increased but not significantly (P>0.05) as harvest age increased, while leaf yields declined. In a feeding study with Bunaji cows in mid-lactation, dried brewers' grains (DBG) and sweet potato forage (SPF) were compared as supplements to a diet of green panic (*Panicum maximum*) (9.3% crude protein). Dry matter (DM) intake of green panic was similar (P>0.05) in both groups, while intakes of supplement, total DM, crude protein and ME for DBG were higher (P<0.05) than for the SPF-supplemented group. Milk yield for the DBG group was 22% higher (P>0.05) than for the SPF group but milk composition was similar in both groups. Rumen dry matter (DM) degradation characteristics were similar (P>0.05) for the two rations. The study suggests that sweet potato foliage could be used as an alternative supplement to DBG for feeding lactating cows but that low levels of milk yield could result. Similar studies covering a full lactation are needed to verify whether the lactation levels could be sustained for long periods or improve with time.

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Introduction

In most African countries, livestock production, mostly from ruminants, accounts for 35–40% of the agricultural gross domestic product (GDP; Hoste 1999). However, availability and quality of conventional feeds/concentrates for livestock fluctuate markedly, and the feeds are expensive. Meanwhile, promising crop residues are not being fully utilised as alternative feed sources for ruminants. Sweet potato (*Ipomoea batatas*) produces not only food for humans but also substantial quantities of forage of good nutritive value capable of providing an above-maintenance ration for ruminants under resource-poor crop-livestock systems (Akinbamijo *et al*. 2002). It has been suggested that the crop could aid in achieving global food security with approximately one-third of its production in developing countries going to animal feeding (Scott 1992). This study was carried out to compare dried brewers' grains (DBG) and sweet potato forage (SPF) as supplements for lactating White Fulani (Bunaji) cows fed a basal diet of green panic (*Panicum maximum*).

Materials and methods

Location of study

The study was carried out on the research farm of the International Livestock Research Institute (ILRI), Ibadan, Nigeria (07°30′N, 03°54′E). Weather conditions were characteristic of the sub-humid tropics. During the study, solar radiation was 14.04 $MJ/m^2/d$, mean relative humidity was 75% (56–95%), temperature ranged from 21.7 to 30.2°C (mean 25.9°C) and rainfall was 1648 mm over 139 d.

Crop establishment and diets

Sweet potato was established in August 2000 on a 25 × 32 m sandy loam plot. The plot was sprayed with pre-emergence herbicides before establishing the crop using disease-free vines carrying about 4 nodes, with 2 nodes buried below ground level at 45° to the top of the ridge. Planting space was 0.25 m within rows, with 1 m between rows. An initial study was conducted to obtain basic information on the optimal stage to harvest sweet potato. Sub-plots were set up as a randomised complete block design to compare 3 harvesting times (12, 16 and 20 weeks after planting; WAP). Forage and tuber yields were estimated by sampling from four 1 m^2 quadrats (as replicates) at each of the 3 harvesting dates. Sampling spots were randomly selected along the 2 diagonals of the plots on each occasion.

The SPF used in the feeding study was harvested at 16 WAP from existing plots on the Research Farm, which had received a side dressing of compound inorganic fertiliser (NPK 15:15:15) at the rate of 250 kg/ha, and was manually chopped to about 25 cm using machetes. Green panic was also harvested on existing unfertilised paddocks on the ILRI Research Farm at 10–12 WAP and chopped to 25 cm using a stationary forage chopper and served as the basal diet.

Feeding trial

A total of 12 multiparous Bunaji cows, weighing on average (± s.d.) 249±35.7 kg (204–319 kg) and in mid-lactation, were used for estimating dry matter intake and milk yield, when fed a basal ration of green panic supplemented with either DBG or fresh SPF. Cows were allocated to treatments on the basis of initial milk yields determined by hand-milking, with calves used to initiate milk let-down, one week before commencing the trial. The rations fed to the 2 groups of 6 cows were:

Ration 1 = 70% green panic + 30% dried brewers' grains, and
Ration 2 = 70% green panic + 30% sweet potato forage.

The 21-day study was set up as a completely randomised design (CRD) with 2 treatments (Ration 1 and Ration 2), while individual cows served as replicates. The rations were fed separately *ad libitum* in 2 equal portions at 08.00 and 16.00 h to cows housed in individual pens measuring about 2 m × 3 m. The green panic and supplements were offered at levels estimated to supply about 70% and 30%, respectively, of the expected daily *ad libitum* consumption of the rations at an intake of 2.5% of bodyweight. Feeds offered and refused (orts) were recorded daily to determine dry matter intake. The green panic and sweet potato forage were harvested daily and fed fresh to the cows. Samples of both feed offered and feed refused were collected, oven-dried at 60°C for 72 h, bulked and preserved for chemical analysis. Pre-trial rations fed to cows comprised green panic supplemented with either DBG or cottonseed meal. Cows were fed the experimental rations for a 14-day adjustment period before measurements commenced during Days 15–21.

Chemical analysis

The samples of oven-dried feed offered and feed refused were further dried at 105°C for about 6 h to eliminate residual moisture before being ground through a 1 mm screen for chemical analysis. About 1 g samples were weighed into crucibles and placed in a muffle furnace at 500°C for 24 h to determine ash content, while organic matter concentration was computed by difference (AOAC 1990). The crude protein concentration (total nitrogen × 6.25) was determined according to the micro-Kjeldahl method, while crude fat was determined by ether extraction (AOAC 1990). Similarly, neutral detergent fibre, acid detergent fibre and acid detergent lignin were determined according to prescribed standard procedures (Van Soest and Robertson 1985). Non-structural carbohydrate (NSC) was computed by difference as NSC = 100 – CP% – Fat% – NDF% – Ash%. Metabolisable energy (ME) was estimated according to the model suggested by MAFF (1984) as ME (MJ/kg DM) = 13.5 – 0.15*ADF% + 0.14*CP% – 0.15*Ash%. Milk samples were analysed for total solids, ash, protein (as %N × 6.38), fat and lactose. Milk protein analysis followed the formaldehyde (formal) titration method and fat the Gerber Fat Test procedures described by O'Connor (1994).

Rumen dry matter degradation characteristics

Preliminary analysis of the sweet potato yield data showed that harvesting at 16 WAP gave optimum results in terms of forage and tuber yields, leaf: stem ratio and harvest index. Leaf:stem ratios were determined by first weighing the complete tops as harvested, then separating tops into leaf portion (leaf-blade plus leaf-petiole) and stem (or vine) before computing the leaf:stem ratio (w/w). The harvest index was computed as the proportion of tuber yield to total biomass yield (*i.e.*, tuber plus forage yield) expressed as a percentage as suggested by Mandal (1993). Samples from the 16 WAP sweet potato forage and green panic were then collected, oven-dried at 60°C for 72 h and used to determine *in vivo* rumen degradability. The dried samples were mixed in the ratio of 70% green panic and 30% of either dried brewers' grains (DBG) or sweet potato forage (SPF) dry matter (w/w) and incubated in the rumens of 3 N'Dama steers for 6, 12, 24, 36, 48, 72 and 96 h. The N'Dama steers used for the rumen degradability studies were maintained on a basal diet of maize stover supplemented with 1.5 kg/hd/d for 10 d preceding and throughout the incubation period. Dry matter disappearance data ($\boldsymbol{p}$) at the end of each incubation period were then fitted into the model $\boldsymbol{p} = \boldsymbol{a} + \boldsymbol{b}(1 - e^{-ct})$ suggested by Ørskov and McDonald (1979) and modified by McDonald (1981), where: $\boldsymbol{a}$ = rapidly soluble fraction; $\boldsymbol{b}$ = slowly degradable fraction; $\boldsymbol{c}$ = rate of degradation of $\boldsymbol{b}$; and ($\boldsymbol{a} + \boldsymbol{b}$) = potential degradability.

Statistical analysis

Data from the rumen dry matter degradation study were subjected to analysis of variance (ANOVA) as a completely randomised design with 3 treatments and 3 replications. Data from the feeding trial were also subjected to ANOVA procedures as a completely randomised design with 2 treatments and 6 replications. All data analyses were carried out with the aid of a standard statistical package (SAS 1999). Mean separation was carried out using LSD at the 5% probability level, where *F*-tests were significant.

Results

Agronomic study

Forage yields and leaf:stem ratio decreased (P<0.05) as harvesting age increased from 12 to 20 weeks after planting (WAP), while harvest index increased (Table 1). Yields of both marketable and unmarketable tubers increased as date of harvest was delayed but differences were not significant (P>0.05), especially between 16 and 20 WAP.

Chemical composition

Data for chemical composition and metabolisable energy contents of green panic, dried brewers' grains (DBG) and sweet potato forage (SPF) showed significant differences between feedstuffs for all parameters measured (Table 2). Dried brewers' grain contained more crude protein and crude fat than sweet potato forage. While ME concentrations were higher in DBG than SPF, differences were not significant (P>0.05).

Rumen dry matter degradation study

Rumen DM degradation after incubation for 48 h did not differ between the two supplementation treatments (P>0.05) (Table 3).

Table 1. Forage and tuber yields, leaf:stem ratio and harvest index (± s.d.) of sweet potato at 12, 16 and 20 weeks after planting (WAP).

Parameter	Harvest date			LSD (P=0.05)
	12 WAP	16 WAP	20 WAP	
Forage yield (t/ha DM)	2.62±0.613	1.73±0.611	1.45±0.427	0.379
Leaf:stem ratio	2.38±0.617	1.42±0.375	0.87±0.230	0.289
Tuber yield (t/ha DM)				
Marketable tubers	6.98±1.576	7.46±1.487	8.47±2.538	1.475
Non-marketable tubers	0.59±0.374	0.77±0.343	1.55±1.277	0.541
Harvest index[1] (%)	74±6.7	83±3.1	87±3.6	3.3

[1] Harvest index = (Tuber DM yield/total DM yield) × 100.

Table 2. Chemical composition (g/kg DM) and metabolisable energy (MJ/kg DM) of green panic and supplements "as fed".

Nutrient	Green panic	Dried brewers' grains	Sweet potato forage
Dry matter (as-fed basis)	215b[2]	834a	93c
Ash	86c	110b	175a
Organic matter	838a	823b	740c
Crude protein	93c	244a	186b
Crude fat	20b	35a	20b
Neutral detergent fibre	732a	535b	469c
Acid detergent fibre	475a	471a	448b
Acid detergent lignin	76b	134a	136a
Non-structural carbohydrate	69b	76b	150a
Metabolisable energy[1]	6.5b	8.5a	7.0ab

[1] Estimated from MAFF (1984): ME (MJ/kg DM) = 13.5 – 0.15*ADF% + 0.14*CP% – 0.15*Ash.
[2] Means within rows followed by different letters are significantly different.

Table 3. Rumen dry matter degradation characteristics (g/kg DM) of mixtures of green panic and dried brewers' grains or sweet potato forage.

Diet	Rumen dry matter degradation characteristics[1]				
	48-h	***a***	***b***	***c*** (part/h)	PD
70% Green panic + 30% dried brewers' grains	446	107	553	0.019	660
70% Green panic + 30% sweet potato forage	486	92	552	0.025	644
Mean	466	100	553	0.022	652
LSD	60	43	229	0.0154	234

[1] ***a***, ***b*** and ***c*** are constants estimated from model $p = a + b(1 - e^{-ct})$, where ***a*** = rapidly soluble fraction; ***b*** = slowly degradable fraction; ***c*** = rate of degradation of ***b***; **PD** = potential degradability (***a*** + ***b***).

Nutrient intake

Dry matter (DM) intake (expressed as both kg/d and g/kg $W^{0.734}$) of green panic was similar (P>0.05) for cows on both treatments but intake of DBG was double that of SPF (P<0.05) (Table 4). Total DM intake of the 70% green panic-30% DBG was higher than that of the green panic-sweet potato ration. Intakes of both crude protein (P<0.001) and metabolisable energy (P<0.01) were higher for the DBG-supplemented cows than for the SPF-supplemented cows.

Milk yield and composition

Daily milk yield and composition did not differ significantly (P>0.05) between treatments (Table 5), although cows fed green panic-DBG gave 22% more milk than those fed green panic-SPF.

Discussion

The results of this study suggest that feeding sweet potato forage as a supplement (about a third of dietary intake) to cows fed a basal diet of green panic forage could result in milk yields of about 1150 mL/d. While the ration containing dried brewers' grain produced 22% more milk than that containing the sweet potato forage, it is well to remember that DBG comprised 53% of the ration consumed, while SPF was only 37% of the ration. The differences in milk yield on the two rations were not significantly different but were certainly biologically significant for this breed of cow, which is generally considered a triple-purpose breed (work; meat; milk). The small group sizes (6 cows per treatment) and large variation in milk yield between cows within treatment groups might explain why the differences were non-significant. Intake data indicate that cows fed green panic-DBG consumed 39% more dry matter, containing 88% more crude protein and 56% more ME than those fed green panic-SPF, which should have resulted in higher milk yields. A complicating factor could be that carry-over effects from the feeding regime the cows experienced before being fed on the trial rations masked the true value of the two diets. Let-down issues with the cows could have been a further complicating factor.

Table 4. Dry matter, crude protein and metabolisable energy intakes by Bunaji cows fed green panic supplemented with dried brewers' grains and sweet potato forage in mid-lactation.

Diet	LWt (kg)	Dry matter intake (kg/d)				Nutrient intake	
		Green panic	Supp	Total	% LWt	CP (kg)	ME (MJ/d)
Green panic + dried brewers' grains	240 (56)[1]	3.34 (60)	3.73 (68)	7.07 (128)	2.9	1.22	52.0
Green panic + sweet potato forage	258 (59)	3.24 (55)	1.86 (32)	5.10 (87)	2.0	0.65	33.4
LSD	46 (7.8)	0.93 (15.9)	0.47 (9.2)	1.07 (17.6)		0.15	7.3

[1] Figures in parenthesis are intakes per unit of metabolic live weight (g/kg $W^{0.734}$) of cows.

Table 5. Yields and composition of milk from Bunaji cows fed green panic supplemented with dried brewers' grains (DBG) and sweet potato forage (SPF) during mid-lactation.

Performance parameter	Ration 1[1]	Ration 2	LSD
Mean live weight of cows (kg)	240	258	46
Daily milk yield (mL/d)	1421	1166	861
Milk composition (g/kg)			
Total solids	134.3	133.7	17.1
Fat	38.1	38.7	5.2
Solids-not-fat	96.2	95.0	12.1
Ash	7.5	7.3	0.5
Protein	35.9	36.7	3.9
Lactose	52.8	51.0	7.9

[1] Ration 1: 47% green panic + 53% DBG; Ration 2: 64% green panic + 36% SPF.

The recorded ME concentration in the sweet potato forage was similar to the average value for crop residues of less than 7.5 MJ/kg DM reported by Makkar *et al*. (2002). The computed ME concentrations in Rations 1 and 2 were 7.1 and 6.7 MJ ME/kg DM, respectively, while the corresponding ME intakes were 52 and 33.4 MJ ME/d and crude protein intakes were 1.22 and 0.65 kg/d. These differences resulted from the large differences in supplement intake on the two rations (Table 4). The ME intakes for both diets were above the daily 0.44 MJ/kg $W^{0.734}$ (Adebowale 1981) and 0.495 MJ/kg $W^{0.75}$ (Ikhatua 2000) (about 24.6 and 25.9 MJ ME/d, respectively) minimum recommended ME requirements for maintenance of Bunaji breeds of cattle in a humid tropical environment. The marked differences in ME and CP intakes on the two rations should have resulted in different levels of animal performance, as was reflected in the different milk yields by the two groups. Since the requirement for milk production is 6.7 MJ/kg milk (ARC 1965), the two groups of cows should have produced about 4.03 L/d and 1.25 L/d, respectively.

However, the recorded milk yields suggest that either the ME in the sweet potato group was utilised more efficiently than that of the DBG-supplemented group, or energy was being used for different physiological purposes in the two groups. Bunaji cows (also known as White Fulani, White Bororo, White Kano, Yakanaji and Akou) are found mostly in tropical and semi-arid climatic environments of Nigeria and Cameroon. Genetically, this breed typically supports low levels of milk production (1.76–3.40 L/d), for which they are primarily utilised (Williamson and Payne 1989; Pagot 1992). Since calves were used to stimulate let-down, one can only speculate on what percentage of the actual milk yield of cows in the two groups was recorded in this study. In addition, cows were in mid-lactation, so yields would be expected to fall at the lower end of the range.

Results of the study on effect of harvest time on sweet potato yield and yield components tend to support those by Larbi *et al*. (2007) that harvesting between 12 and 16 weeks after planting (WAP) in the savanna zone of Nigeria, and 20 WAP in the humid forest zone, could maximise tuber yields and forage quality. The results pose challenges regarding the optimum time to harvest the crop to achieve both high tuber yields and high quality sweet potato forage that would be useful for feeding to livestock. Our decision to harvest the sweet potato foliage at 16 WAP was to ensure optimal nutritive value of the foliage as a supplement for the green panic forage as considerable leaf was being lost as the vines aged. However, to meet requirements for tubers for human consumption, harvesting could be delayed until 20 WAP, when tuber yields would be highest (Table 1). Harvesting SPF periodically from about 16 WAP would cause only limited reduction in tuber yields as a trade-off (Dahniya *et al*. 1985; Nwinyi 1992). Based on the observed forage DM yield at 16 WAP (Table 1) and the DM intakes of sweet potato forage (Table 4), 0.5 ha of the crop could be used to provide sufficient forage to be fed as a supplement to green panic for 3 cows for 2.5 months.

Determining the rumen DM degradability of the diets provided an indication of the relative digestibility of the diets through the potential degradability values (Table 3). However, it is well to remember that the DBG ration examined in this aspect of the study was different from that which was consumed by the cows. The mean ***PD-values*** recorded were higher than 500 g/kg DM, suggesting that the diets were adequate for feeding to low-producing animals (FAO 1995). The differences in chemical composition and ME concentration of the diets were not particularly reflected in the rumen 48-h DM degradation data and ***PD-values,*** indicating that both diets could have similar effects on the cows. The difference in the rapidly soluble fraction (***a-value***), rate of degradation of ***b*** (***c-value***) and the recorded NSC suggests that the DBG would provide the needed by-pass nitrogen for hindgut digestion although this could slow rumen microbial activities. On the other hand, sweet potato forage by its relatively high ***a-value***, higher NSC and ***c-value*** would facilitate rumen fermentation as it would serve as both a readily available source of carbohydrate and nitrogen for microbial protein synthesis.

Conclusion

The study suggests that sweet potato forage could serve as a replacement or partial substitute for dried brewers' grains as a supplement for lactating cows fed a basal diet of green panic or other roughages, rather than being allowed to rot away on most farms including some national agricultural research institutes involved in sweet potato breeding. However, only low milk yields would be sustained on a ration similar to that used in this study. By harvesting forage at regular intervals from about 16 WAP, large quantities of fodder could be obtained. Socio-economic studies on this varied use of the crop are warranted to quantify the overall benefits and/or losses, which would ensue from this change from current practice. The feeding studies need to be repeated for a full lactation with larger numbers of animals to ensure that milk yields could be sustained, before a general recommendation could be made on the use of this feeding system by commercial farmers.

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