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Screening Sweetpotato Germplasm for Starch, Flour and Feed Quality Characteristics

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ABSTRACT

Studies were conducted to screen newly collected sweetpotato germplasm for starch, flour, and feed quality traits. Fresh tuber and forage yields were evaluated in the first study using 13 genotypes while in the second study tuber dry matter (DM) and starch contents were investigated using 17 genotypes both in augmented incomplete block designs. In the third study, voluntary dry matter intake (VDMI) was determined in White Fulani cows fed with sole fresh sweetpotato forage in early lactation, and potential degradation trial in three rumen-fistulated N'Dama steers using the *in-sacco* technique in a completely randomized design. Mean (±SE) fresh tuber yield (13.00 ± 0.471 t/ha) was higher ($P < 0.01$) in control than test genotypes (13.20 versus 12.94 t/ha) while, flour yield (35.71 ± 1.351) was lower in control than test genotypes (34.80 versus 38.74 g/100 g). Tuber DM ranged ($P < 0.01$) from 44.27 to 67.11 g/100 g, and starch content from 19.80 to 30.60 g/100 g, with a negative correlation (r = -0.65; $P = 0.05$) observed between both parameters. The orange- and white-fleshed genotypes were similar ($P > 0.05$) in the agronomic parameters determined. Forage crude protein (CP) ranged ($P < 0.05$) from 116.1 to 221.0 g/kg DM, neutral detergent fibre (NDF) from 376.4 to 482.0 g/kg DM, and β-carotene from 320 to 460 μg/100 g. Voluntary DMI, percent of liveweight, and potential degradability of DM varied ($P < 0.05$) from 7.4 to 9.0 kg/d, 2.9 to 3.7%, and 837 to 885 g/kg DM, respectively. The positive correlation (r = 0.92; $P = 0.05$) between flour yield and forage NDF suggests the possibility of developing models for predicting forage quality based on both agronomic and nutritional data.

Keywords: animal performance, dry matter, forage composition, sweetpotato tuber, yield

INTRODUCTION

Sweetpotato (*Ipomoea batatas* (L.) Lam.) is a perennial tuber crop and considered to be the closest substitute for cassava (*Mannihot esculenta* Crantz) root, which is a major staple energy source in Nigeria. It is amongst the world's most important, versatile, and yet under exploited food-feed crop (CIP 1999). In Nigeria, the total production of fresh tuberous root of the crop has continued to rise from a meagre 0.53 million tons in 1990 (AFLF 1990), to 2.47 million tons in 2000 (FAO 2001), 2.52 million tons in 2005 (FAO 2005), and 3.64 million tons in 2008 (FAO 2008). However, the literature shows that much of the increase in production could be attributable to increasing land area under cultivation to the crop as yield per unit area has been on a continuous decline over the last two decades. In an attempt to improve productivity per unit area cultivated, a three-pronged approach was adopted to breed for increased crop yield, nutritional value, and industrial traits such as tuber dry matter, starch and flour contents to stimulate utilization for food and feed. Although the crop has, in recent times, received close attention due to its apparent but neglected potentials, there have been numerous challenges associated with the selection of dual- or multi-purpose varieties that would meet current and emerging market demands of farmers with small land holdings, including prospective farmers, as well as commercial and industrial users (Fuglie *et al*. 2006).

Subhadhirasakul *et al*. (2001) demonstrated from their study on starches from taro (*Colocasia* spp.) and sweetpotato tubers as potential alternative sources of starch used in medicinal tablet formulations that, the binding and disintegrating performance of both crops were similar to that of commercial corn starch. Also, the selection of sweetpotato genotypes for high starch contents and digestibility has been proposed as an effective way to increase sweetpotato tuber feed efficiency (Zhang *et al*. 2002). Furthermore, increased attention on the use of orange-fleshed β-carotene-rich varieties of sweetpotato shows that much still needs to be done for identifying varieties that are nutritionally suitable for humans and able to meet demands for sweetpotato starch in industries such as pharmaceutical, confectionery, and livestock/poultry (Bashaasha *et al*. 2001; Iwe 2002; Shih *et al*. 2006). Thus, a series of studies were initiated in 2005 to facilitate the early release of promising new varieties, from 56 genotypes originally obtained from the International Potato Centre (CIP) sub-station in Uganda, into the Nigerian farming system. The overall goal of the studies was to make such varieties more attractive to farmers who must make conscious decisions and choices of choosing and evaluating/testing newly introduced β-carotene-rich sweetpotato genotypes for improved human health, rural income, and crop/livestock productivity. Therefore, the objective of this study was to evaluate and screen sweetpotato germplasm collection for starch, flour, and feed quality characteristics.

MATERIALS AND METHODS

Weather conditions during agronomic studies

The agronomic study was conducted in the 2006 and 2007 growing seasons at the National Root Crops Research Institute (NRCRI), Umudike, Nigeria. The total and average rainfalls were 2420.7 and 201.7 ± 49.67 mm (range: 0-464.8 mm) with 142 rainy days in 2006, while they were 2038.3 and 169.9 ± 38.88 mm

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Table 1 Average monthly rainfall (mm), temperature (°C) and relative humidity (%) at Umudike, Nigeria during the 2006 and 2007 growing seasons.

Month	Rainfall				2006 Temperature		2007 Temperature		Relative humidity	
	2006	Day	2007	Day	Min.	Max.	Min.	Max.	2006	2007
Jan	0	0	76.6	3	24	33	21	34	70.0	36.0
Feb	62.9	2	81.9	3	24	33	24	35	70.5	59.0
Mar	35.5	5	131.9	6	24	34	24	35	70.0	59.0
Apr	78.4	9	136.0	9	24	33	23	32	70.5	71.0
May	444.9	17	202.8	15	23	31	22	32	79.0	74.5
Jun	354.0	18	237.3	15	22	31	22	30	78.0	79.0
Jul	187.6	18	303.4	16	23	30	22	30	82.5	77.0
Aug	464.8	26	133.7	15	22	29	22	29	80.5	81.5
Sept	319.9	18	483.1	20	22	29	22	30	83.0	78.5
Oct	335.6	19	237.4	19	22	31	22	30	78.0	77.0
Nov	112.1	8	14.2	1	23	31	23	31	70.0	74.0
Dec	25.0	2	0	0	22	32	22	32	55.0	63.0
Min.	0	-	0	-	20	29	21	29	55.0	36.0
Max.	464.8	-	483.1	-	24	34	24	35	83.0	81.5
Mean	201.7	-	169.9	-	23	31	22	32	73.9	69.1
SE	49.67	-	38.88	-	0.4	0.5	0.3	0.6	2.28	3.75
Total	2420.7	142	2038.3	122	-	-	-	-	-	-

(range: 0-483.1 mm) with 122 rainy days in 2007. The minimum and maximum temperatures in 2006 were 23 ± 0.4°C and 31 ± 0.5°C, while the corresponding figures in 2007 were 22 ± 0.3°C and 32 ± 0.6°C, respectively. Similarly, the relative humidity for 2006 was 73.9 ± 2.28% (range: 55.0-83.0%) and for 2007 it was 69.1 ± 3.75% (range: 36.0-81.5%) indicating that 2007 was relatively drier than 2006. Details of the weather conditions in 2006 and 2007 are presented in **Table 1**. The soil at the site was also characterised as sandy-loam soil with an average pH (H_2O) of 4.8.

Experiment 1: Fresh tuber and forage yields

Thirteen sweetpotato (11 of which were obtained from the International Potato Centre (CIP) in Uganda and three checks (TIS 87/0087; TIS 8164; TIS 2532.OP.1.13) from the National Root Crops Research Institute (NRCRI) in Nigeria) genotypes were evaluated in 2006. The experiment was conducted using the augmented incomplete block design with four blocks according to the procedures described by Federer (1991). Of the 13 genotypes evaluated, 10 were the topmost performers based on preliminary results of tuber and flour yields that were compared with the three check genotypes. Each block comprised 14 plots each measuring 6 m^2 with an intra-row spacing of 30 cm and an inter-row spacing of 1 m. The crops were planted 19th July 2006 with weeding done at 42 days after planting (DAP) before inorganic fertilizer (NPK 15: 15: 15) was applied at the rate of 400 kg/ha. The crops were later harvested on 12th December 2006 at 146 DAP and fresh tuber yields determined per plot. Samples of tuber were then dried at 60°C for 72 h and milled through 1 mm and retained for chemical analysis. The flour yield was determined from a known weight of freshly harvested sweetpotato tubers as:

$$\text{Flour yield (g/100 g)} = \frac{\text{Weight of flour obtained}}{\text{Initial weight of fresh tubers}} \times 100$$

Experiment 2: Tuber dry matter and starch contents

Experiment 2 was carried out in 2007 to evaluate a new CIP collection. The same field protocol as in Experiment 1 above was adopted to evaluate the selected cultivars. The crops were planted on 19th July 2007 and harvested on 9th January 2008 at 153 DAP. Sweetpotato tuber samples were then collected from the selected introduced genotypes for dry matter, starch content, and fresh tuber flesh colour determination.

Experiment 3: Voluntary DM intake and potential degradation study

Fresh foliage from genotypes TIS 8164, TIS 87/0087, and TIS 2532.OP.1.13 were harvested at 112 DAP and sole-fed to two multiparous Bunaji (White Fulani) cows each in early lactation to determine voluntary dry matter intake. The cows used were about three years old with mean (±SE) bodyweight of 250 ± 25.4 kg (range: 199-276 kg). The trial on voluntary dry matter intake lasted 21 d (14 d adjustment and 7 d collection) in a completely randomized design (CRD). The animals had free access to clean drinking water and mineral blocks. Also, samples of the harvested forages were oven-dried at 60°C for 72 h and milled to 2.5 mm size for degradation study. Thereafter, about 3 g of the 2.5 mm dried samples were used to determine the potential degradability (*PD*) of the forages in the rumens of three mature N'Dama steers using duplicate nylon bags about 10 × 17 cm and 41 µm pore-size. The degradation study was conducted according to the procedures described by Ørskov and McDonald (1979) and modified by McDonald (1981). The animals used for the degradation study were fed a diet of 75% maize stover and 25% wheat bran (w/w). The potential degradability (*PD*) was estimated as $PD = a + b$ from the non-linear model $p = a + b(1 - e^{-ct})$ using nlin procedures of SAS Institute Inc (2002). In the experimental model, p = rumen degradation data fitted into the model, a = rapidly soluble fraction, b = slowly degradable fraction, c = rumen degradation rate of b, and t = incubation periods of 6, 12, 24, 36, 48, 72, and 96 h.

Chemical analysis

A portion of the oven-dried sweetpotato forage collected was milled through a 1.0 mm sieve and used for chemical analysis. The product of the micro-Kjeldahl nitrogen (% N) and 6.25 was used to complete crude protein content (AOAC 2002; ID 954.01). Neutral detergent fibre and acid detergent fibre contents were analysed using the procedures described by Van Soest *et al*. (1991). Non fibre carbohydrate (NFC) was computed as NFC = 100 - CP % - Fat % - NDF % - Ash %. The β-carotene contents in the dried forage samples were also determined (AOAC 2002; ID 970.64).

Statistical analysis

Data analysis was carried out using the SAS 9.1 for Windows software package (SAS Institute Inc. 2002). The proc means and proc corr procedures were run on the parameters in each of the three experiments. Data from Experiments 1 and 2 were analysed as a randomized complete block while data from Experiment 3 were analysed as completely randomized design to determine possible correlations between any two parameters of primary interest. Tests for significant statistical differences were carried out using the Fisher's LSD *t*-test.

RESULTS

Fresh tuber and flour yields

Results of fresh tuber and flour yields of 13 sweetpotato collection were significantly different ($P < 0.01$) as presented in **Table 2**. The fresh tuber yield was lowest in genotype 400004 and highest in genotype 440034, while the corresponding trend for flour yield was from 25.00 g/100 g in genotype 440016 to 40.10 g/100 g in genotype TIS 87/0087 (one of the control genotypes). When the data were pooled to compare mean performance between the new test genotypes and the three afore-listed check genotypes, the figures were 12.94 versus 13.20 t/ha, and 38.74 versus 34.80 g/100 g, respectively. The results of fresh tuber and flour yields indicate that the mean of the 10 test top performing genotypes (12.94 t/ha) was not significantly different ($P > 0.05$) from the mean of the three control genotypes (13.20 t/ha). However, mean flour yield was higher in the 10 topmost performing test genotypes than in the three check genotypes (38.74 versus 34.80 g/100 g). No significant relationship was observed between fresh tuber and flour yields.

Tuber dry matter and starch contents

The variations in the 17 sweetpotato germplasm evaluated are presented in **Table 3** where three of them (Ex-Igbariam; TIS 8164; TIS 2532.OP.1.13) served as local checks for the rest of the 14 genotypes. The table indicates that tuber dry matter content ranged from 44.27 g/100 g in Carrot C (orange-fleshed) to 67.11 g/100 g in genotype 440031 (orange-fleshed). The starch content varied between 19.80 g/100 g in the yellow-fleshed Ex-Igbariam genotype to 30.60 g/100 g in the white-fleshed TIS 8164 genotype. Three genotypes (440031; NASPOT 5; 199024.2) exhibited higher tuber dry matter contents while, three other genotypes (Carrot C; 400004; NASPOT 1) recorded higher tuber starch contents than the local checks Ex-Igbariam and TIS 2532.OP.1.13 alone. There was a negative correlation ($r^2 = -0.65$; $P = 0.05$) between tuber dry matter and starch contents for the 17 genotypes.

Table 2 Means of 13 sweetpotato collection evaluated for fresh tuber yield (t/ha) and flour yield (g/100 g) at Umudike, Nigeria in 2006 and 2007.

Genotype	Category	Fresh tuber yield	Flour yield
187017.1	Test	15.33	38.20
NASPOT 1	Test	13.50	35.00
440034	Test	16.17	27.00
440016	Test	12.83	25.00
440163	Test	12.67	38.50
BRONDAL	Test	11.67	39.30
440293	Test	13.67	33.00
440170	Test	12.17	34.50
1870162	Test	10.67	37.50
400004	Test	10.67	40.00
TIS 8164	Control	12.05	39.77
TIS 87/0087	Control	14.97	40.10
TIS 2532.OP.1.13	Control	12.58	36.35
Min.–Max.		10.67 - 16.17	25.00 - 40.10
Mean ± SE		13.00 ± 0.471	35.71 ± 1.351
Significance		$P < 0.01$	$P < 0.01$

Table 3 Means of 17 sweetpotato germplasm evaluated for flesh colour, tuber dry matter (DM) and starch contents (g/100 g) at Umudike, Nigeria in 2006 and 2007.

Genotype	Category	Tuber DM content	Starch content	Flesh colour
440031	Test	67.11	20.00	Orange
199024.2	Test	61.51	23.53	Orange
440141	Test	56.53	24.27	Orange
440203	Test	56.26	22.90	Orange
199034.1	Test	55.45	25.40	Orange
Carrot C	Test	44.27	27.00	Orange
1870162	Test	52.93	24.20	Orange
187017.1	Test	54.67	25.27	Orange
NASPOT 1	Test	51.26	28.87	Orange
NASPOT 5	Test	62.38	23.60	White
NASPOT 2(1)	Test	58.67	26.67	White
NASPOT 3	Test	52.97	24.33	White
400004	Test	55.90	27.13	White
Santo Amaro	Test	54.95	25.47	Yellow
TIS 8164	Control	53.19	30.60	White
TIS 2532.OP.1.13	Control	58.12	24.33	White
Ex-Igbariam	Control	60.03	19.80	Yellow
Min.–Max.		44.27 - 67.11	19.80 - 30.60	
Mean ± SE		56.25 ± 1.230	24.90 ± 0.666	
Significance		$P < 0.01$	$P < 0.01$	

Table 4 Variations in mean fresh tuber yield, flour yield and starch contents between three orange-fleshed and three white-fleshed sweetpotato germplasm studied at Umudike, Nigeria.

Parameter	Orange-fleshed	White-fleshed	Mean	$FLSD_{0.05}$
Tuber dry matter (g/100 g)	60.81 ± 7.220	55.74 ± 2.469	58.27	12.231
Fresh tuber yield (t/ha)	13.17 ± 2.348	11.77 ± 0.986	12.47	4.082
Flour yield (g/100 g)	36.90 ± 1.682	38.71 ± 2.044	37.80	4.244
Starch content (g/100 g)	22.60 ± 2.272	27.35 ± 3.141	24.98	6.214

Effects of flesh colour on tuber components

The results of Fisher's LSD *t*-test carried out on three genotypes each of orange-fleshed and white-fleshed sweetpotato genotypes showed no significant difference ($P > 0.05$) in terms of tuber dry matter content, fresh tuber yield, flour yield, and starch content of tuber (**Table 4**). However, the results indicated that tuber dry matter and fresh tuber yields were, numerically (9.1 and 11.8%), higher in the orange-fleshed genotypes while, flour yield and starch content were also 4.9 and 21.0% higher in the white-fleshed genotypes.

Tuber yields and forage composition

Results on the analysis of relationship of fresh tuber and flour yields versus forage composition from five genotypes are shown in **Table 5**. There were significant differences ($P < 0.05$) in fresh tuber and flour yields as well as forage composition among the five genotypes. Fresh tuber yield was lowest in genotype 400004 and highest in genotype 440293 while, it was the reverse for flour yield. The β-carotene content of the forage ranged between 320 µg/100 g for genotype 187017.1 and 460 µg/100 g for genotype 440170 but recorded no relationship with either fresh tuber or flour yield. A positive correlation ($r^2 = 0.92$; $P = 0.05$) was recorded between flour yield and neutral detergent fibre content of the forage. Conversely, there was a negative correlation ($r^2 = -0.91$; $P = 0.05$) between forage crude protein versus non fibre carbohydrates and between non-fibre carbohydrates versus neutral detergent fibre.

Tuber yields and animal performance

Table 6 presents the mean variations in fresh tuber and flour yields, forage composition, and performance by cattle fed the forage from three sweetpotato genotypes. Genotype TIS 87/0087, consistently, gave higher fresh tuber ($P < 0.05$) and flour ($P < 0.01$) yields while, genotype TIS 2532.OP.1.13 recorded higher figures for forage crude protein ($P < 0.05$), neutral detergent fibre ($P < 0.01$), and acid detergent fibre ($P < 0.01$) contents. Voluntary dry matter intake varied ($P < 0.01$) from 7.4 kg/d to 9.0 kg/d representing between 2.9% of liveweight for genotype TIS 87/0087 to 3.7% of liveweight for genotype TIS 8164. The potential degradability was significantly lower ($P < 0.01$) for geno-

Table 5 Variations in mean fresh tuber yield, flour yield, and forage composition of five new sweetpotato germplasm studied.

Parameter	Sweetpotato genotype*					Mean ± SE
	187017.1	440293	440034	400004	440170	
Fresh tuber yield (t/ha)	15.33[ab]	13.67[bc]	16.17[a]	10.67[d]	12.17[cd]	13.60 ± 1.01
Flour yield (g/100 g)	38.20[ab]	33.00[c]	27.00[d]	40.00[a]	34.80[bc]	34.60 ± 2.264
Forage composition (g/kg DM):						
Crude protein	176.4[ab]	116.1[c]	159.2[b]	203.9[a]	170.0[b]	165.1 ± 14.31
Non fibre carbohydrate	226.7[b]	316.4[a]	302.5[a]	182.6[c]	234.1[b]	252.5 ± 25.10
Neutral detergent fibre	43.13[a]	400.5[b]	376.4[b]	448.1[a]	437.9[a]	418.8 ± 13.25
Acid detergent fibre	378.0[ab]	356.1[ab]	346.5[b]	385.0[ab]	402.5[a]	373.6 ± 10.06
β-carotene (µg/100 g)	320[d]	390[b]	370[bc]	340[cd]	460[a]	376 ± 24.2

*Means with different superscripts in the same row are significantly different ($P < 0.05$).

Table 6 Variations in mean fresh tuber, flour, forage composition and animal performance by cattle fed forage from three sweetpotato genotypes in Nigeria.

Parameter	Sweetpotato genotype*			Mean ± SE	Significance
	TIS 8164	TIS 87/0087	TIS 2532.OP.1.13		
Fresh tuber yield (t/ha)	12.05[b]	14.97[a]	12.58[b]	13.20 ± 0.898	$P < 0.05$
Flour yield (g/100 g)	39.77[ab]	40.10[a]	36.35[b]	38.74 ± 1.199	$P < 0.01$
Forage composition (g/kg DM):					
Crude protein	191[a]	145[b]	221[a]	186 ± 22.1	$P < 0.05$
Neutral detergent fibre	458[b]	467[ab]	482[a]	469 ± 7.0	$P < 0.01$
Acid detergent fibre	447[b]	456[ab]	471[a]	458 ± 7.0	$P < 0.01$
Animal performance:					
Dry matter intake (kg/d)	7.4[b]	8.1[ab]	9.0[a]	8.2 ± 0.46	$P < 0.01$
Percent of liveweight (%)	3.7[a]	2.9[b]	3.3[ab]	3.3 ± 0.23	$P < 0.01$
Potential degradability (g/kg)	879[a]	885[a]	837[b]	867 ± 15.1	$P < 0.01$

*Means with different superscripts in the same row are significantly different ($P < 0.05$).

type TIS 2532.OP.1.13 while, genotypes TIS 8164 and TIS 87/0087 recorded similar figures.

DISCUSSION

Fresh tuber and flour yields

Although sweetpotato is considered a secondary crop in Nigeria, sustained research attention was not accorded to it until mid-last decade following the realisation of the wide knowledge gap between the actual potentials of the crop and the available information in the literature (Akoroda and Nwokocha 1996). The differences recorded for fresh tuberous root and flour yields amongst the evaluated genotypes are expected given the apparent differences in genetic composition. Larbi *et al.* (2007) reported the findings from one of such studies initiated in 1997 showing genotypic differences amongst 18 sweetpotato genotypes (including the three control genotypes on **Table 2** adjudged to be most promising based on previous agronomic and nutritional evaluation studies). The recorded average lower fresh tuber yield in the ten test genotypes (12.94 t/ha) and the mean of the three check genotypes (13.20 t/ha) suggests that there is still room for improving them through breeding and selection to surpass the control genotypes.

In a similar manner, the encouraging mean flour yield by the 10 test genotypes also call for further improvements to ensure higher flour yield per ha. Since a significant relationship between fresh tuber and flour yield was not found in this study, it is possible to breed these genotypes for improved fresh tuber and flour yield without sacrificing one or the other. Flour yield in sweetpotato is imperative to make the selected genotype(s) commercially and industrially relevant, as well. Besides the yield of flour from the different sweet-potato genotypes, the chemical composition will also determine the nutritional quality. Banser *et al.* (2000) recorded lower palatability of sweetpotato flour-based diets over maize-based diet with the observation of varietal differences among the sweetpotato meals. But in a rapid visco analysis study to determine the pasting properties of mixtures of wheat flour and tuber starches, it was observed that sweet potato starch could be used as a partial substitute for wheat flour in some wheat-based products (Zaidul *et al.* 2007).

Tuber dry matter and starch contents

Tuber DM and starch contents are two important traits in the breeding and selection of sweetpotato genotypes for commercial and industrial purposes. The tuber DM is an indicator of tuber quality in sweetpotato, and it is an important raw material quality for the sweetpotato-based processing industry (Rodriguez 1999). Crops with tuber DM greater than 30.00 g/100 g are considered adequate for processing (Mok *et al.* 1997). Ray and Ravi (2005) investigated sweetpotato post harvest spoilage and control measures in the tropics and observed that, sweetpotato varieties varied in their root DM content, and that low root DM content accounted for their high curing efficiency. The higher DM and starch contents recorded could be partly due to the crop selection phases the genotypes have undergone, or the harvesting in December or January that is characterised by zero to minimum rainfall and relative humidity as depicted in **Table 1** (Zhang *et al.* 2002; Chen *et al.* 2003). The weather conditions to which the crops were exposed at the time of harvest might have resulted to the tuberous roots slowly losing substantial amounts of moisture to the surrounding soil and hence the reported high dry matter contents. However, the range (44.27-67.11 g/100 g) in dry matter contents observed in the present study is higher than the 35.00 g/100 g range reported for a sample population made of 58% white-fleshed and 85% yellow-fleshed sweetpotato clones (Brabet *et al.* 1998) and the 18.6-36.7 g/100 g dry matter for three Chinese sweetpotato varieties reported by Chen *et al.* (2003).

The range of 19.80-30.60 g/100 g starch content obtained in the current study (**Table 3**) points to the high potential of the new sweetpotato collection investigated to serve as raw materials to the starch industry with an average starch content that is within the upper limits of 5.3-28.4 g/100 g (Woolfe 1992) and 10.7-27.8 g/100 g (Chen *et al.* 2003) earlier reported. The highly significant variations and correlation between tuber dry matter and starch contents among the 17 genotypes studied showed that the genotypes with superior traits could successfully be identified (**Table 3**). The existence of negative correlation between the two traits implies that there would be sacrifice for one whenever there was a gain in the other. The recorded negative correlation between tuber dry matter and starch contents in the present study appear to corroborate other reports since the genotypes with lower dry matter also exhibited high postharvest processing efficiency for starch yield (Ray and Ravi 2005). But in an earlier study by Zhang *et al*. (2002) it was observed that, a positive correlation existed between tuber dry matter and starch contents from six sweetpotato genotypes studied. The fewer numbers of genotypes (six) evaluated in their study, compared to the 17 investigated in the present study, might be partially responsible for the recorded differences in correlation patterns. Other factors such as crop management, weather conditions, the season of the year, storage time, and genetic make-up might also be implicated for the reported discrepancy in correlation pattern (Tian *et al*. 1991; Yempew *et al*. 2001; Rahman *et al*. 2003).

Effects of flesh colour on tuber components

A comparison of the orange-fleshed genotypes and the white-fleshed genotypes shows that the average (±SE) tuber dry matter, fresh tuber yield, flour yield, and starch content were similar. The observed higher variation amongst the orange-fleshed genotypes also indicates that further breeding and selection could result to varieties with both above-average tuber dry matter and starch contents, in spite, of the recorded inverse relationship (**Table 3**). On the other hand, flour yield and starch contents were more uniform with little deviations in the orange-fleshed genotypes compared to the white-fleshed genotypes considered in **Table 4**. Although it was not assayed for in the tubers for the present study, it is believed that the orange and yellow tuber flesh colour suggests the presence carotenoid pigments (predominantly β-carotene), which is a precursor of vitamin A. As a rule of thumb, it is known that the deeper the pigmentation of the tuber flesh the higher the provitamin A content.

In a study to determine the physicochemical characteristics and processing properties of white and red sweetpotato varieties it was observed that, there were significant differences in their protein, vitamin C, calcium, potassium, and sodium contents (Onuh *et al*. 2004). However, they reported no significant difference between the red and white sweetpotato flours in terms of some physical properties such as oil and water absorption, emulsion capacities, bulk densities, swelling and foaming capacities. Shih *et al*. (2006) demonstrated from their study that rice-sweetpotato pancakes had substantially higher β-carotene contents that can enrich the dietary status, especially, in populations threatened with low dietary β-carotene consumption. Thus, genotypes with high concentrations of β-carotene can result in higher accumulation of the pigment in bovine species due to their lower efficiency of vitamin A synthesis in enterocytes with the concentration in milk depending on the dietary source such as genotype (Nozière *et al*. 2006). With such knowledge it could be said that the materials so investigated in the present study do possess high nutritive value since about 79% were either of orange or yellow flesh colour.

Tuber yields and forage composition

The recorded fresh tuber and flour yields for the five genotypes suggest that genotype 187017.1 out-performed the rest four genotypes (**Table 5**) and thus, would be ideal for farmers interested in the production of sweetpotato flour for commercial use. In terms of forage utilization for the potential feeding of livestock, genotype 440034 with a crude protein content of 159.2 g/kg DM and neutral detergent fibre content of 376.4 g/kg DM appears to be most appropriate. Generally, the five genotypes contain crude protein contents that were above the minimum 70 g/kg DM being the recommended minimum requirement for dry cattle and 120 g/kg DM crude protein said to be ideal for lactating cows. Also, considering the significance of β-carotene in the health of farm animals as well as the composition of their products such as milk and meat fat, forage from genotypes with relatively high β-carotene contents such as the 370 μg/100 g recorded for genotype 440034 would be suitable as choice feed resource for livestock.

Tuber yields and animal performance

Table 6 shows that the three local control genotypes were further evaluated to include both agronomic and nutritional components. In terms of agronomic parameters, genotype TIS 87/0087 performed better and could be most ideal for the sole purpose of producing tuber and flour. However, combining the results of forage composition alone ranks genotype TIS 8164 better than the rest with respect to its high crude protein and relatively low neutral detergent fibre contents. The observed voluntary dry matter intake of 3.7% of liveweight also ranks genotype TIS 8164 higher than the rest two genotypes since the potential degradability value was also high. Observed results from the study are in agreement with previous studies reports (Etela *et al*. 2008; 2009). The overall scenario indicates the superiority of genotype TIS 8164 based on the optimum yields and forage quality parameters observed.

CONCLUSION

The results from the above studies are relevant because a good knowledge of the physicochemical properties of newly developed sweetpotato germplasm can ensure the development of models for better crop breeding programmes. Also, such models can facilitate planning for optimum storage and processing time suitable for different genotypes to match specific industry needs. Processing fresh tubers into flour will ameliorate the storage and transportation difficulties associated with sweetpotato production, processing, and consumption especially in the developing world. Furthermore, the evaluation of feed quality of the new germplasm will position them for easy adoption by smallholder crop and livestock farmers, who may, equally, be interested in both tuberous root and fodder yields and quality. The orange-fleshed sweetpotato genotypes have shown both good agronomic and nutritional characteristics that make them comparable, and even superior in some traits, to the existing white- or yellow-fleshed local check sweetpotato genotypes.

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