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Proximate Characterization of Selected Ugandan Sweetpotato (*Ipomoea Batata* L.) Varieties For Food And Feed

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Abstract

Sweet potato *Ipomoea batatas* L. (Lam.) is a symbol in the fight for a global nutrition plan that can save millions of children and help build a healthier and more productive future. Sweet potato is relied on as a source of calories since its vines and/or storage roots can be used for direct human consumption, as well as providing inexpensive, protein-rich fodder for animals. However, characterisation of sweet potato varieties with optimal proximate characteristics suitable for both food and feed has not been done. This study sought to characterise selected Ugandan sweet potato varieties to identify those that are more suitable for food and feed purposes. The characterization was based on proximate analysis of vines and root tubers. The data obtained was analysed using Minitab version 17 and statistical package for social sciences (SPSS) Version 20 software packages. Proximate analysis showed that there were highly significant differences ($p \leq 0.001$) among the 11 varieties in all the root parameters evaluated. On the other hand, vine characteristics, including ash content, dry matter, organic matter, nitrogen, *in vitro* organic matter digestibility, crude protein, and metabolisable energy significantly varied ($p \leq 0.001$) among the varieties. However, there were no significant differences in neutral detergent fibre, acid detergent fibre and acid detergent lignin ($p \geq 0.05$) among the varieties. This study enables selection of sweet potato varieties with optimal characteristics for both food and feed use. It also contributes to the advancement of on-going research on sweet potato, specifically towards sustainable food production.

Keywords: Sweet potato; Proximate analysis; Diversity; Nutritional analysis; Vines and root tubers

Introduction

Globally, sweet potato is ranked as the third most important root crop after potato and cassava, and is placed sixth after rice, wheat, potatoes, maize and cassava in world food crop production [1,2]. Due to its importance as a food crop, it is ranked fourth in developing countries after rice, wheat, and maize [3]. Previous reports have estimated global sweet potato production at 105 million metric tons as at 2013, 95% of which is grown in developing countries [4].

Previous findings obtained from field trials shows that the average crop yield of dual-purpose sweet potato is 8 ton/ha, as compared to1.5 and 4.3 ton/ha for maize and beans, respectively. Also, the average fodder yield for dual-purpose sweet potato amounts to 14.6 ton/ha, compared to 3.4 ton/ha for maize and beans, and 9.3 ton/ha for the mixed crops [5]. Economically, the average net returns for dual-purpose sweet potato are 56,806 KES/ha compared to 13,428 for maize-beans and 26,188 KES/ha for the mixed crops [6].

High productivity under marginal conditions, high nutritional composition and low input requirements make sweet potato a potential remedial crop for many rural farmers [7]. Moreover, its usefulness for both food and feed make it preferable in areas where land availability is constantly declining [5]. Sweet potato thrives well on soils of limited fertility, is relatively drought resistant, matures in a relatively short period and is therefore suitable for climate change adaptation in these times of global warming [8]. In addition to food and feed value, sweet potato has medicinal qualities due to the presence of anthocyanins in purple fleshed varieties, which are useful in the prevention of cancer [9]. The crop also provides good ground cover, thus preventing soil erosion and improving soil fertility in the long run. Conservation of available farmers' preferred varieties is critical for exploitation of additional traits, such as drought tolerance and high yields in the face of climate change [10].

Malnutrition due to deficiency of micronutrients in the diet affects the health of over half the world's population. Vitamin A deficiency in particular has become a major concern since it causes blindness and weak immune system in humans. Vitamin A deficiency is more severe in sub-Saharan Africa, where an estimated 32 per cent of preschool-aged children are affected. In addition to these health and nutritional challenges, land availability for natural grazing is rapidly diminishing due to the increasing human population. The value of maize stalk as livestock feed is, as with other crop residues, limited by its poor digestibility and low crude-protein and mineral content. There is, therefore, a need for adoption of crops that can be efficiently used for both food and feed, such as sweet potato. Sweet potato grows in marginal conditions, requires little labour and little or no chemical fertilisers. It is a cheap and nutritious solution for developing countries, which need to grow more food on less area to sustain rapidly growing populations. It also provides inexpensive, high-protein fodder for animals. Thus, this study involved characterization of selected sweet potato varieties based on proximate analysis to determine those that are more suited for both food and feed use.

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Materials and Methods

Plant materials

Sweet potato clones generated from a polycross of 11 Ugandan sweet potato parents were analysed in this study. The crossing was done at the International Potato Center (CIP-Uganda). The parents were: Rwabuganda, Kyebandula, Naspot1, Kyabafuruki, Magabari, NaspotII, New Kawogo, Dimbukabukulula, Kigabali, BND145L and Shock. The seeds were germinated at KALRO-Kiboko and the seedlings transplanted into the experimental plot after establishment.

Scarification of sweet potato seeds

Sweet potato seeds do not have a dormancy period but maintain their viability for many years. Seed germination is therefore difficult and requires scarification by mechanical abrasion or chemical treatment [11]. In this case, a chemical treatment was done for scarification using concentrated sulphuric (VI) acid. Seeds were placed in plastic mesh and submerged in concentrated sulphuric (VI) acid until the acid started turning dark (10-40 minutes). They were then rinsed in running water. After scarification, the seeds were planted in seedling trays containing sterile soil, watered and placed under net tunnel shade. The seedling trays were kept moist until germination occurred and seedlings established. Before transplanting, the seedlings were hardened by reducing the moisture of the soil in the seedling trays.

Germination and early screening stages

In the early screening stages, plants were raised from true seeds. Germination of the seedlings was done in trays containing sterilised soil. The percentage germination was calculated and an average of 10 repeats recorded for each family. A selection of seedlings exhibiting dual-purpose characteristics based on leaf lobes was done. The selected seedlings were transplanted to the field organised according to their families on mounds 1m apart, with 30 cm between the seedlings. Observation yield trials (OTs) were carried out in order to discard those which clearly did not meet a lowest acceptable value of the given descriptors for dual-purpose varieties, as shown in Table 1.

Morphology	Acceptable description	CIP score
Twining	Moderately twining	**5**
Plant Type	Spreading(151-250cm)	**7**
Ground Cover	High(75%-90%	**7**
Vine Internode	(i)length-Intermediate(6-9cm) (ii)Diameter-Thick (10-12mm)	**5**
Vine Pigmentation	(i)Predominant vine color -Green ii)secondary vine color-Absent	**1**
Vine Tip Pubescence	Sparse	**3**
Mature Leaf Shape	Either: 1.Rounded 2.Reniform 3.Cordate 4.Tiangular	**1, 2,3,4**
Leaf Lobes Type	No lateral lobes or Very slight (teeth)	**0, 1**
Leaf Lobe Number	1	**1**
Shape Of Central Leaf Lobe	(i)Absent (ii)toothed	**0,1**
Mature Leaf Size	1.Large (16-25cm)	**7**
Abaxial Leaf Vein Pigmentation	Green	**2**
Foliage Color	(i)mature leaf color-Green (ii)immature leaf color-Green	**2** **2**
Petiole Length	Intermediate(21-30cm)	**5**
Petiole Pigmentation	Green	**1**
Storage Root	(i)Storage root shape; Round elliptic, Elliptic, Long-Elliptic (ii)Storage root cortex thickness-Intermediate (3mm) (iii) Storage root skin color a. Predominant skin colour-Any b. secondary skin color-Absent (iv)storage root flesh color a. Predominant flesh color-Any b. Secondary flesh color; Either: Absent. White, cream, yellow, orange.	**2,3,8** **5** **1-9** **0** **1-9** **0-4**

Table 1: Vegetative and storage roots characteristics used for evaluation of sweet potato varieties for food and feed use (CIP, AVRDC, IBPGR (1991).

Proximate analysis of the selected varieties

Nutritional content analysis was carried out using the Near Infrared Reflectance Spectroscopy (NIRS) method [12] at ILRI-Ethiopia Analytical Services Laboratory. The measurements were repeated 10 times in each sample and thus an average of 10 replicates was recorded. Immediately after harvesting, selected root and vine samples from each variety were packed into labelled plastic polythene bags and taken to the University of Nairobi Kabete campus laboratory for oven drying.

Before drying, the root samples were first washed with running tap water to remove soil particles. Root samples were prepared by cutting each root lengthwise into four sections with kitchen knives, and then two opposite sections of each of the sectioned roots were taken to obtain samples of approximately 50 g by slicing them using a stainless steel kitchen knife. They were then allowed to dry in the oven and packed into brown paper bags that were labelled according to the names of the 11 families. Dried samples were weighed and milled into flour in a stainless steel mill at KALRO-Muguga. The milled samples were placed in sealed transparent bags.

Data analysis

The proximate data was analysed using Analysis Of Variance (ANOVA) followed by Tukey's post hoc statistical tools as implemented in the statistical package for social sciences (SPSS) Version 20 software package. Minitab version 17.0 software (State College Pennsylvania, USA) was used to carry out cluster analyses and principal component analysis. Cluster analyses based on proximate parameters yielded dendrograms that were used to examine the phenotypic relatedness among the 11 sweet potato varieties. Principal Component Analysis (PCA) was carried out to determine the major determinants of variation and correlation based on the 18 descriptors and 10 proximate parameters among the varieties.

Results

Germination frequency among selected sweet potato varieties

Seed germination of the sweet potato varieties ranged between 52 and 82 per cent. Naspot II had the highest seed germination rate (82 per cent) while Magabari had the lowest (52 per cent) (Table 2).

Variety	Number of seeds planted	Number of seeds that germinated	Germination (%)
Rwabuganda	4000	2896	72.40
Kyebandula	2000	1339	66.90
Naspot I	1000	667	66.7
Kyabafuruki	2000	1124	56.20
Magabari	2000	1031	51.50
Newkawogo	2000	1344	67.20
Naspot II	1000	820	82.00
Dibuka- bukulula	2000	1532	76.60
Kigabali	1000	750	75.00
BND145L	3000	2131	71.00
Shock	2000	1592	79.60

Table 2: Germination percentages among the varieties.

Proximate analysis

Nutritional components of root tubers of the various varieties: Analysis of variance indicated highly significant differences ($p \leq 0.001$) among the 11 varieties in all the root parameters evaluated based on dry matter basis. (Table 3). Dry matter (DM) was above 90 per cent in all 11 varieties. Ash content was highest in Dibuka bukulula and New-Kawogo varieties and lowest in Naspot II. Based on organic matter (OM), all varieties showed very high percentages of above above 82 per cent. Nitrogen content was quite low, ranging between1.1 and 1.7. Among the 11 varieties, crude protein (CP) was highest in Rwabuganda and lowest in Kyabafuruki. Neutral detergent fibre per cent (NDF %) ranged between44.0 and 51.6 whereas Acid detergent fibre per cent (ADF %) on a dry matter basis ranged between 31.0 and 47.7. Acid detergent lignin per cent (ADL %) ranged between 8.5 and 13.9. Invitro Organic Matter digestibility per cent (IVOMD %) was above 60 in all 11 varieties. Metabolizable energy (ME) ranged between 9.9 and 12.0 among the varieties (Table 3).

Nutritional components of vines of the various varieties: Table 4 shows analysis of variance (ANOVA) among the 11 varieties on vine characters based on dry matter. Dry matter, Ash, Organic Matter, Nitrogen, TIVOMD, Crude Protein, and Metabolisable Energy (ME) were all significantly different ($p \leq 0.001$) among the varieties. However, there were no significant differences among the varieties in NDF, ADF, and ADL ($p \geq 0.05$).

Comparison of proximate parameters in the various varieties: Figure 1 is a dendrogram constructed from data sets of the mean values of all 10 proximate parameters of the 11 sweet potato varieties. It shows that the varieties separated into two super clusters, A and B. Super cluster A had two sub-clusters, I and II, each subdividing further into two other smaller groups, while super cluster B was composed of the variety Naspot II. Sub-cluster I was composed of sub-sub-clusters

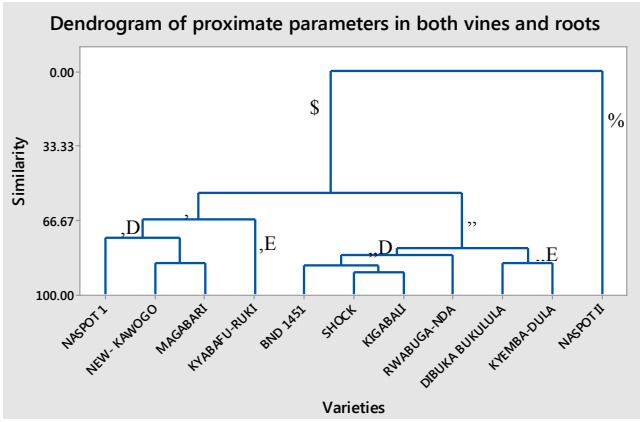

Figure 1: UPGMA dendrogram, based on Euclidean distance coefficient of 11varieties, generated by proximate parameters.

Variety	DM%	ASH	OM%	N%	CP%	NDF%	ADF%	ADL%	IVOMD%	ME(MJ/Kg)
Naspot 1	91.4 ± 0.07^{bc}	14.8 ± 0.54^{b}	85.1 ± 0.54^{a}	1.4 ± 0.08^{abcd}	9.0 ± 0.56^{abcd}	48.2 ± 0.82^{c}	47.5 ± 0.95^{b}	13.0 ± 0.35^{b}	62.4 ± 0.76^{a}	10.2 ± 0.17^{ab}
BND 145L	90.9 ± 0.07^{a}	14.6 ± 0.54^{b}	85.3 ± 0.54^{a}	1.3 ± 0.06^{abcd}	8.6 ± 0.40^{abcd}	45.5 ± 0.55^{abc}	45.0 ± 1.19^{b}	12.1 ± 0.36^{b}	64.6 ± 0.67^{a}	10.3 ± 0.18^{ab}
Shock	90.8 ± 0.08^{a}	14.6 ± 0.38^{b}	85.3 ± 0.38^{a}	1.5 ± 0.07^{bcd}	9.7 ± 0.46^{bcd}	44.3 ± 0.63^{a}	42.6 ± 0.94^{b}	11.6 ± 0.46^{b}	65.8 ± 0.60^{a}	10.4 ± 0.14^{ab}
Dibuka Bukululua	90.8 ± 0.09^{a}	15.7 ± 0.67^{b}	84.2 ± 0.67^{a}	1.6 ± 0.07^{cd}	10.4 ± 0.47^{cd}	45.3 ± 0.68^{abc}	44.2 ± 0.83^{b}	12.2 ± 0.33^{b}	64.5 ± 0.61^{a}	10.0 ± 0.19^{a}
Rwabuganda	90.6 ± 0.15^{a}	14.8 ± 0.79^{b}	85.1 ± 0.79^{a}	1.7 ± 0.08^{d}	10.9 ± 0.55^{d}	46.4 ± 0.68^{abc}	41.3 ± 1.63^{b}	11.6 ± 0.32^{b}	66.5 ± 0.99^{a}	10.4 ± 0.22^{ab}
Kigabali	90.9 ± 0.07^{ab}	14.8 ± 0.55^{b}	85.6 ± 0.55^{a}	1.5 ± 0.08^{bcd}	9.8 ± 0.54^{bcd}	44.8 ± 0.48^{ab}	42.0 ± 1.0^{b}	11.6 ± 0.38^{b}	65.7 ± 0.62^{a}	10.5 ± 0.16^{ab}
New Kawogo	90.9 ± 0.1^{abc}	15.7 ± 0.87^{b}	84.2 ± 0.87^{a}	1.4 ± 0.12^{abcd}	8.8 ± 0.79^{abcd}	46.7 ± 0.87^{abc}	47.7 ± 0.99^{b}	13.9 ± 0.34^{b}	62.2 ± 0.74^{a}	9.9 ± 0.2^{a}
Magabari	91.1 ± 0.1^{abc}	15.04 ± 0.72^{b}	84.9 ± 0.72^{a}	1.3 ± 0.06^{abc}	8.2 ± 0.41^{abc}	44.2 ± 0.67^{a}	45.7 ± 0.98^{b}	13.4 ± 0.34^{b}	62.0 ± 0.77^{a}	9.9 ± 0.17^{a}
Naspot II	90.7 ± 0.13^{a}	10.3 ± 1.17^{a}	89.6 ± 1.17^{b}	1.2 ± 0.08^{ab}	7.7 ± 0.55^{ab}	47.7 ± 0.84^{bc}	31.0 ± 4.6^{a}	8.5 ± 1.2^{a}	73.7 ± 2.6^{b}	12.0 ± 0.45^{c}
Kyabafuruki	91.4 ± 0.10^{c}	12.6 ± 20.62^{ab}	87.3 ± 0.62^{ab}	1.1 ± 0.07^{a}	7.0 ± 0.48^{a}	51.6 ± 0.91^{d}	46.2 ± 1.5^{b}	12.4 ± 0.52^{b}	64.3 ± 0.96^{a}	11.2 ± 0.21^{bc}
Kyembadula	91.0 ± 0.05^{abc}	15.7 ± 0.49^{b}	84.2 ± 0.49^{a}	1.6 ± 0.09^{bcd}	10.0 ± 0.01^{bcd}	44.0 ± 0.85^{a}	45.1 ± 1.4^{b}	13.0 ± 0.54^{b}	63.6 ± 0.78^{a}	9.9 ± 0.16^{a}

Key: DM (%) - Dry Matter per cent; OM -Organic Matter; N (%) - Nitrogen per cent on dry matter basis; CP (%)- Crude Protein per cent on dry matter basis; ADF (%)-Acid Detergent Fibre per cent on dry matter basis; NDF (%) - Neutral Detergent Fibre per cent on dry matter basis; IVOMD (%) - *In vitro* Organic Matter Digestibility per cent; ADL (%) - Acid Detergent Lignin per cent on dry matter basis; ME-Metabolisable Energy
abcd=Means followed by the same letters within a column are not significantly different, Tukey's test ($p \leq 0.05$)

Table 3: Mean values of proximate analysis (on dry matter basis) of sweet potato tubers of various varieties.

Variety	DM%	ASH	OM	N%	CP%	NDF%	ADF%	ADL%	IVOMD%	ME(MJ/Kg)
Naspot 1	90.2 ± 0.10^{a}	5.40 ± 0.73^{ab}	94.5 ± 0.73^{ab}	0.7 ± 0.06^{ab}	4.8 ± 0.42^{ab}	49.7 ± 0.75^{a}	13.3 ± 2.2^{a}	4.10 ± .64^{a}	82.6 ± 1.25^{a}	13.9 ± 0.21^{b}
BND 145L	90.5 ± 0.11^{ab}	5.5 ± 0.20^{ab}	94.4 ± 0.20^{ab}	0.8 ± 0.03^{ab}	5.0 ± 0.03^{ab}	50.7 ± 0.70^{a}	10.5 ± 0.56^{a}	2.7 ± 0.32^{a}	88.4 ± 0.31^{d}	13.4 ± 0.08^{ab}
Shock	90.7 ± 0.08^{ab}	5.9 ± 0.23^{ab}	94.0 ± 0.23^{ab}	0.8 ± 0.06^{ab}	5.0 ± 0.38^{ab}	49.4 ± 0.88^{a}	10.9 ± 0.59^{a}	2.6 ± 0.25^{a}	87.2 ± 0.55^{cd}	13.4 ± 0.11^{ab}
Dibuka Bukululua	90.3 ± 0.14^{ab}	6.2 ± 0.28^{b}	93.7 ± 0.28^{a}	1.0 ± 0.06^{b}	6.5 ± 0.43^{b}	51.0 ± 0.36^{a}	11.5 ± 0.55^{a}	3.2 ± 0.45^{a}	87.5 ± 0.59^{cd}	13.1 ± 0.13^{a}
Rwabuganda	90.3 ± 0.09^{ab}	6.0 ± 0.20^{ab}	93.9 ± 0.20^{ab}	0.9 ± 0.05^{ab}	6.0 ± 0.35^{ab}	51.4 ± 0.51^{a}	11.5 ± 0.52^{a}	3.2 ± 0.32^{a}	86.9 ± 0.39^{bcd}	13.2 ± 0.10^{a}
Kigabali	90.4 ± 0.13^{ab}	6.1 ± 0.31^{b}	93.8 ± 0.31^{a}	0.9 ± 0.07^{ab}	6.0 ± 0.43^{ab}	50.8 ± 0.61^{a}	12.2 ± 0.72^{a}	3.4 ± 0.47^{a}	86.4 ± 0.42^{bcd}	13.2 ± 0.11^{a}
New Kawogo	90.7 ± 0.10^{b}	5.4 ± 0.21^{ab}	94.5 ± 0.21^{ab}	0.8 ± 0.06^{ab}	5.4 ± 0.37^{ab}	50.0 ± 0.40^{a}	10.4 ± 0.63^{a}	2.3 ± 0.30^{a}	88.5 ± 0.27^{d}	13.5 ± 0.07^{ab}
Magabari	90.6 ± 0.10^{ab}	5.1 ± 0.20^{ab}	94.8 ± 0.20^{ab}	0.7 ± 0.06^{ab}	4.6 ± 0.38^{ab}	49.9 ± 0.35^{a}	11.5 ± 0.59^{a}	2.9 ± 0.25^{a}	87.1 ± 0.45^{cd}	13.6 ± 0.07^{ab}
Naspot II	90.7 ± 0.05^{b}	4.4 ± 0.11^{a}	95.5 ± 0.11^{b}	0.6 ± 0.03^{a}	4.2 ± 0.23^{a}	50.6 ± 0.41^{a}	10.8 ± 0.29^{a}	2.5 ± 0.17^{a}	87.7 ± 0.20^{cd}	13.9 ± 0.05^{b}
Kyabafuruki	90.3 ± 0.13^{ab}	5.2 ± 0.54^{ab}	94.7 ± 0.54^{ab}	0.7 ± 0.07^{ab}	4.7 ± 0.47^{ab}	50.6 ± 0.60^{a}	12.4 ± 2.3^{a}	3.5 ± 0.67^{a}	84.1 ± 1.3^{ab}	13.8 ± 0.2^{b}
Kyembadula	90.3 ± 0.17^{ab}	5.1 ± 0.35^{ab}	94.8 ± 0.35^{ab}	1.0 ± 0.11^{b}	6.5 ± 0.74^{b}	51.3 ± 0.71^{a}	9.8 ± 0.83^{a}	2.6 ± 0.54^{a}	85.3 ± 0.5^{abc}	13.9 ± 0.15^{b}

Key: DM (%) - Dry Matter per cent; OM -Organic Matter; N (%) - Nitrogen per cent on dry matter basis; CP (%)- Crude Protein per cent on dry matter basis; ADF (%)-Acid Detergent Fibre per cent on dry matter basis; NDF (%) - Neutral Detergent Fibre per cent on dry matter basis; IVOMD (%) - *In vitro* Organic Matter Digestibility per cent; ADL (%)-Acid Detergent Lignin per cent on dry matter basis; ME-Metabolisable Energy
abcd=Means followed by the same letters within a column are not significantly different, Tukey's test ($p \leq 0.05$)

Table 4: Mean values of proximate analysis (on dry matter basis) of sweet potato vines of various varieties.

Ia and Ib. Sub-sub-cluster Ia contained the Naspot I, Newkawogo and Magabari varieties, while sub-sub-cluster Ib was composed of Kyabafuruki. Sub-sub-cluster IIa grouped together the varieties BND145L, Shock, Kigabali and Rwabuganda, while sub-sub-cluster IIb contained Dimbuka bukulula and Kyembadula varieties.

Principal component analysis (PCA) based on proximate parameters: PCA was performed for all 10 proximate parameters in both vegetative and tubers among the 11 sweet potato varieties, as indicated in Table 5. Out of the 10 traits, two principal components exhibited more than one Eigen value and showed about 97.1 per cent variability among the characters under investigation. PC1 showed 57.4 per cent, PC2 showed 30.0 per cent, while PC3 had 9.6 per cent variability among the varieties for the characters studied. PC1, PC2, PC3 had Eigen values of 5.74, 3.0 and 2.23 respectively (Table 5). PC1 was highly and positively correlated in terms of Organic Matter (OM), Dry Matter (DM), Neutral Detergent Fibre (NDF), In vitro Organic Matter Digestibility (IVOD), and Metabolisable Energy (ME). However, all the other parameters were negatively correlated. Most of the proximate parameters for PC2 were highly and positively correlated, while Ash content, Nitrogen (N), Crude Protein (CP) and In vitro Organic Matter Digestibility (IVOD) were negatively correlated. PC3 exhibited very high negative correlation in all the parameters, except DM, Ash content and IVOD, which were positively correlated as shown in Table 5.

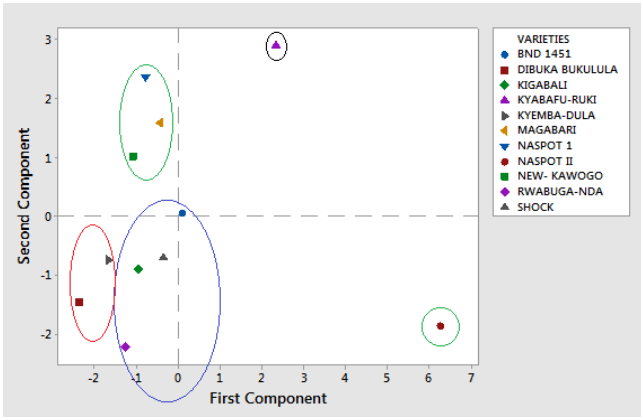

Figure 2: Clustering of 11 sweet potato varieties based on 10 proximate parameters.

	PC1	PC2	PC3
Eigen Value	5.74	3.0	0.96
% Total Variance	57.4	30	9.6
% Cumulative	57.4	87.4	97.1
Proximate parameters(% on dry matter basis)	**Eigen vectors**		
Dry Matter	0.122	**0.487**	**0.419**
Ash	**-0.414**	-0.016	0.063
Organic Matter	**0.413**	0.009	-0.057
Nitrogen	-0.325	-0.332	-0.171
Crude Protein	-0.317	-0.344	-0.212
Neutral Detergent Fibre	0.2	0.197	**-0.805**
Acid Detergent Fibre	-0.284	0.414	-0.12
Acid Detergent Lignin	-0.304	0.383	-0.13
***In Vitro* Organic Matter Digestibility**	0.258	**-0.419**	0.159
Metabolisable Energy(MJ/Kg)	0.396	0.038	-0.196

Table 5: Eigen vectors, Eigen values, total variance and cumulative variance among 11 sweet potato varieties based on 10 proximate parameters.

Based on the 10 proximate analysis parameters the 11 varieties were clustered into four different groups, as shown in Figure 2. The first quadrant contained the variety Kyabafuruki, while the second quadrant grouped the Naspot I, Magabari and New Kawogo varieties together. In the third quadrant, the varieties Kyebandula, Dimbuka bukulula, BND 145L, Kigabali and Shock were grouped together. The fourth quadrant consisted only of the variety Naspot II, as shown in Figure 2.

Discussion

Sweet potato has been shown to be a potential remedial crop for many tropical smallholder farmers due to its high productivity and low input requirements, while its usefulness for both food and feed (dual purpose) makes it very attractive in resource-poor regions where land availability is decreasing [13]. Moreover, mixed crop-livestock systems have a crucial role to play in the bio-economic improvement of outputs for smallholder farmers, and improving methods for sweet potato cultivation could increase their ability to feed their animals and to provide nutrition for their households [5].

Sweet potato roots have high carbohydrate content, low amounts of proteins and minerals and almost no fat [14]. In this study, all the varieties had high dry matter (above 90 per cent). This is consistent with other studies [15]. In addition, all 11 varieties exhibited high digestibility, a good quality for fodder. The sweet potato root is rich in energy, as it contains 80-90 per cent carbohydrate on a dry matter basis [16]. The nutrient composition of the leaves, stems and tubers varies, depending on the time of harvesting as well as on genotypic differences [17]. The tuberous root has superior dry matter and crude protein content compared with stems. Crude protein content in the dry matter of sweet potato vines ranges from 16-29 per cent [18]. However, the varieties in this study have low crude protein on a dry matter basis, and previous research shows that crude protein (on a dry matter basis) in sweet potato vines is low (14.2 per cent). The composition of sweet potato vines, in percentage terms on a dry matter basis, has been reported as 23.4crude fibre, 40.3 NDF, 32.8 ADF, 16 ADL, 18 CP, 21.6 ash, and15.8 MJ gross energy/kg. The varieties in this study were rated above the given threshold in all the parameters, except for CP and ME. Thus, the high nutrient content of the vines can be used to improve the diet of livestock and the quality of manure.

Conclusions

When a variety contains a high amount of total dry matter, both in roots and vines, it is recommended as a dual-purpose variety. All the varieties in this study can be classified as "high duals" due to their high nutrient content and high fodder availability. Morphologically, based on the root/forage ratio, Naspot I is a high dual variety, Rwabuganda and New Kawogo are low dual varieties and BND145L, Shock, Dimbuka bukulula, Kigabali, Magabari, Naspot II, Kyabafuruki and Kyebandula are forage varieties. However, in terms of nutrition, all 11varieties qualified as dual purpose due to their high dry matter content in both the vines and tuberous roots. Based on this study, it is recommended that the variety Naspot I could be grown to help resolve food versus feed competition in smallholder crop-livestock operations between humans and livestock. This is because the vines and roots of Naspot I are suitable as feed for animals and the roots are marketable for direct consumption by humans. Further studies should be done to further characterise dual sweet potato varieties using suitable molecular markers. More research should be done on enhancement of protein content in dual purpose sweet potato through methods such as genetic engineering.

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