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QUALITY CHARACTERISTICS, ROOT YIELD AND NUTRIENT COMPOSITION OF SIX CASSAVA (*Manihot esculenta* Crantz) VARIETIES

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ABSTRACT

Six cassava varieties were evaluated in a completely randomised design with three replications at the Gladstone Road Agricultural Centre during 2013. Plants were harvested nine months after planting and evaluated for tuber yield and nutrient composition. They were also assessed for their leaf, stem and root morphological characteristics. Significant differences were seen between the six varieties for all root responses. The variety 'John LaMotte', with a late branching and erect growth habit, produced the highest marketable yield at 19.5 t/ha, followed by 'Fine Leaf', of a similar growth habit, which yielded 16.7 t/ha of marketable tubers. Proximate analyses of the raw pulp taken from the tubers of the six cassava varieties revealed differences in their nutrient and mineral contents. The mean values of sodium, on a dry weight basis, ranged from a low 22.3 mg/100g for 'Cuban White Stick' to a high of 34.9 mg/100g for 'John LaMotte'. The values for potassium ranged from 817.3 mg/100g for 'Cuban White Stick' to 1230.6 mg/100g for 'Blue Mountain'. The ash content varied from 2.3% for 'Cuban White Stick' to 3.0% for 'Blue Mountain'. The cassava varieties were very high in carbohydrates, averaging 31.9% of dry matter. The mean percentage of crude fat found within the fresh cassava pulp ranged from 0.20% to 0.41%. The protein contents for all varieties were very low, ranging from 1.2% to 2.1%. The cassava varieties in this study all had appreciable levels of nutrient and chemical compositions, and can be recommended as a part of a nutritionally balanced diet. The low values reported in this study for protein and mineral content however, suggest that improvements can be made to enhance the nutritional value of this crop through varietal selection.

Cassava (*Manihot esculenta* Crantz)

Introduction:

The cassava (*Manihot esculenta* Crantz) is cultivated mainly in the tropic and sub-tropic regions of the world, over a wide range of environmental and soil conditions. It is tolerant of insect pests and diseases, and is very tolerant of drought and heat stress. The cassava is not a labour intensive crop and produces well on marginal soils. In many of the cassava growing regions of the world, however, the cassava does not achieve its yield potential, due primarily to disease and limited inputs such as fertiliser and irrigation (Siritunga and Sayre, 2004). Estimates of the Food and Agriculture Organisation of the United Nations (FAOSTAT, 2011) put world production of cassava at more than 230 million metric tonnes annually. Major producers of cassava include Nigeria (37.5 million tonnes per annum), Brazil (24.5 million tonnes) and Thailand (22.0 million tonnes). For the Caribbean region, annual production is in excess of 1.2 million tonnes, with The Bahamas contributing about 240 tonnes to this figure.

Freshly harvested cassava roots of the variety 'Cuban White Stick', grown at the Gladstone Road Agricultural Centre

The cassava is an important component in the diets of more than 800 million people around the world (FAO, 2007) and is the third largest carbohydrate food source within the tropical regions, after rice and corn (Ceballos *et al*., 2004). Cassava is referred to as a food security crop (Barratt *et al*., 2006), which can be left in the ground for extended periods of up to two years, until required. It is used mainly as a fresh food item, but is also processed into various food and non-food products, such as starch, flour, beverages, animal feeds, biofuels and textiles.

There is much variation in the nutrient quality of the cassava root (Chaves *et al.*, 2005). In the tropical regions, cassava is the most important root crop and, as a source of energy, the calorific value of cassava is high, compared to most starchy crops (Okigbo, 1980). The starch content of the fresh cassava root is about 30%, and gives the highest yield of starch per unit area of any crop known (Tonukari, 2004). The protein content is extremely low, however, and ranges between 1-3% (Buitrago, 1990; Salcedo *et al.*, 2010). The cassava root contains a number of mineral elements, in appreciable amounts, that are useful in the human diet. The root contains significant amounts of iron, phosphorus and calcium, and is relatively rich in vitamin C (Enidiok, *et al.*, 2008).

There are several thousand varieties of cassava and about 100 related wild species (Hershey *et al*., 1997), with hydrogen cyanide (HCN) contents of their roots ranging from 1-1550 parts per million (ppm) (Cardoso *et al*., 2005). Cassava plants are generally categorised as bitter or sweet, depending upon their cyanide content. The low-HCN, or sweet cassava, has less than 50 ppm of cyanogenic equivalents, while the high-HCN, or bitter cassava has more than 100 ppm (Wilson and Dufour, 2002). According to Adepoju *et al*., (2010), the food value of cassava is greatly compromised by its toxic hydrogen cyanide content. The sweet cassava can be cooked and eaten as they are, while the bitter cassava needs to be processed before being consumed.

A large amount of variation exists among the cassava leaf, stem and root characteristics. These characteristics, which include leaf morphology, stem colour, branching habit and storage root shape and colour, may influence cassava yield (Ntawuruhunga and Dixon, 2010). Other, not so obvious, characteristics include resistance to insect pests and diseases. A proper understanding of these variations in plant characteristics would assist the selection of cassava types with the desired traits. This, in turn, will contribute to improved crop establishment and increased yields.

Among the objectives of the root and tuber crops programme at the Gladstone Road Agricultural Centre are to identify high yielding cassava varieties, to evaluate and preserve cassava germplasm and to provide good quality planting material for local farmers. However, very little documented information on the performance of cassava on the calcareous soils of The Bahamas, under improved agronomic practices, is available. With this present study, efforts are being made to evaluate existing varieties and new introductions for their yield potential under local conditions. Cassava production in The Bahamas could be improved through the introduction of improved varieties and the adoption of improved agronomic practices.

Objective:

The objectives of the present study were to evaluate the nutrient composition and mineral content of six cassava varieties, to examine them for quality and yield of their tuberous roots and to document their leaf, stem and root characteristics. This trial complements the previous trial of 2011, in which three cassava varieties were evaluated for tuber quality and yield.

Materials and Methods:

The study was carried out at the Gladstone Road Agricultural Centre, New Providence, from April 2012 to January 2013. The cassava planting material used in this study, and some of their characteristics, are listed in Table 1. These varieties were obtained from several local farmers and are already a part of their cassava production systems. Their origins could not be independently verified at the time of this study; the information found in Table 1 was obtained from the farmers who supplied the plant material, or identified it as such from stock plants growing at the Gladstone Road Agricultural Centre. Though no nutritional studies have been done to determine the levels of hydrogen cyanide (HCN) within their edible portions, they have been designated by farmers as sweet cassava varieties, with apparently low HCN contents. To date, there have been no reports of HCN toxicity with any of the six varieties evaluated.

Table 1. Characteristics and origin of plant material used in the experiment.

VARIETY	ORIGIN	DESCRIPTION
Blue Mountain	Jamaica	Early branching, spreading
Cuban White Stick	Cuba	Early branching, spreading
Fine Leaf Cassava	Origin unknown, local variety, similar to 'John LaMotte'	Late branching, erect
Haitian Stick	Haiti	Early branching, erect
Honey Dew	Origin unknown, local variety from Eleuthera, similar to 'Blue Mountain'	Early branching, spreading
John LaMotte	Origin unknown, well established local variety	Late branching, erect

The six cassava varieties evaluated in this experiment were established in an open field in single rows in a completely randomised design with three replications, on ridges 1.5 m apart, with a 1.0 m spacing between plants within rows. The planting material consisted of mature stem cuttings of about 20 cm in length, containing between ten and twelve nodes and planted in a vertical position along the top of the ridges. Each plot consisted of ten plants, with data being taken from two plants within each plot, for a total of six plants per variety. Tuber yield was determined from the actual area of each plot, which, according to Romani *et al*., (1993), provides a good estimate of true yield. This is also supported by Neppl *et al*., (2003) whose study indicated that interactions of centre row with border row were insignificant. The usual cultural practices were observed to ensure an even stand of plants in the experimental plots. The cassava trial plots were grown under rain-fed conditions. Plant characteristics (Table 2) were described according to the descriptor list for cassava genetic resources (Biodiversity International, CIAT, 2009).

Table 2. Characteristics observed of cassava plants and system of rating (after CIAT, 2009)

No.	**Characteristic**	**Method of determination**	**Key**
1	Colour of first fully expanded leaf	Observing and estimating	1. Light green 2. Dark green 3. Green-purple 4. Purple
2	Shape of central leaf lobe	Observing and estimating	1. Oblanceolate 2. Linear 3. Elliptic 4. Pandurate (obovate with pair of basal lobes) 5. Lanceolate 6. Other
3	Colour of unexpanded apical leaves	Observing and estimating	1. Light green 2. Dark green 3. Green-purple 4. Purple 5. Other
4	Pubescence of young leaves (newly formed in the transitional stage)	Observing and estimating	1. Sparse 2. Intermediate 3. Dense
5	Petiole colour	Observing and estimating	1. Light green 2. Dark green 3. Green-purple 4. Purple 5. Other
6	Stem colour (observed between 50-100 cm from ground level)	Observing and estimating	1. Silver green 2. Light brown or orange 3. Dark brown 4. Other
7	Storage roots per plant	Counting	
8	Storage root pulp colour (observed immediately after being cut open)	Observing and estimating	1. White or cream 2. Yellow 3. Pink 4. Other
9	Storage root surface colour	Observing and estimating	1. White 2. Cream 3. Light brown 4. Dark brown 5. Other
10	Colour of outer surface of storage root cortex	Observing and estimating	1. White or cream 2. Yellow 3. Pink 4. Purple 5. Other

Samples of the harvested tubers for each of the six cassava varieties were submitted to the Food Safety and Technology Laboratories of the Department of Marine Resources for analyses. The raw cassava pulp was processed, then analysed for biochemical and mineral composition and the values expressed on a dry matter basis. Quality characteristics measured included, moisture, dry matter, protein, crude fat, ash, sodium and potassium.

Methods Used in Analysis of Cassava (Based on A.O.A.C., 1995):

Moisture/Dry Matter - Tubers were peeled, wiped and chopped into small pieces. Triplicate 2g samples were accurately weighed into pre-labelled, pre-weighed dishes and were dried at 130°C to constant weight. Dried samples/dishes were weighed. Moisture content (%) was calculated. Dry matter (%) was calculated by 100 – Moisture content (%).

Other Analyses - Samples were peeled, wiped, chopped and dried in oven. The dried samples were subsequently powdered in a high-speed blender and used for the remainder of the tests.

Ash - Triplicate prepared samples were weighed into pre-weighed, porcelain crucibles. The samples were transferred to a muffle furnace and ashed at 550°C for 8 hours. The crucibles were allowed to cool in desiccators and then weighed. Percentage ash content was calculated.

Protein - Duplicate 1g dried and powdered samples were weighed and digested with H_2SO_4 and K_2SO_4/Se catalyst tablets, using the block digestion method in a Foss Tecator Auto Digestor. The resulting digest was steam distilled into boric acid using a Labconco Rapid Still II. Titration of the distillate with standard HCl was used to estimate crude protein. The method was based on the A.O.A.C. Official Method 2001.11.

Fat - Fat determination carried out by the acid hydrolysis method. 8g samples were weighed in triplicate and digested in acid. The digests were transferred to Monjonnier flasks where the fat was extracted with ethers. The ether extract was transferred into previously dried and weighed flasks and the ethers evaporated and the remaining fat dried and weighed and the % fat calculated.

Sodium and Potassium - Aqueous solutions of ashed samples were aspirated directly into a Cole-Parmer Model 2655-00 flame analyzer. Intensity was compared against a prepared standard curve.

The mean monthly maximum and minimum temperatures for the experimental period were 29.8^{o}C (85.6^{o}F) and 22.4^{o}C (72.3^{o}F), respectively. The total rainfall for the period was 1569.16 mm (61.8 in). Mean monthly sunshine duration for the period was 7.8 h. Weather data (Table 3) on sunshine duration, maximum and minimum temperatures and rainfall for the period under study were obtained from the Meteorological Department of the Commonwealth of The Bahamas.

Table 3. Weather data on rainfall, hours of sunshine and mean maximum and minimum temperatures for New Providence for the period of April 2012 to January 2013, courtesy of the Meteorological Department of The Bahamas.

Month	**Total rainfall (mm/**inches)	**Mean monthly radiation (h)**	**Mean maximum temperature (ºC/**ºF)	**Mean minimum temperature (ºC/**ºF)
April 2012	**326.1**/12.84	**8.9**	**27.9**/82.2	**20.3**/68.5
May 2012	**222.0**/8.74	**6.8**	**29.9**/85.8	**21.6**/70.9
June 2012	**191.5**/7.54	**7.3**	**31.6**/88.8	**24.6**/76.3
July 2012	**190.5**/7.50	**9.1**	**32.4**/90.4	**24.4**/76.0
August 2012	**138.7**/5.46	**8.4**	**32.9**/91.3	**25.3**/77.5
September 2012	**254.3**/10.01	**6.9**	**32.2**/90.0	**24.2**/75.6
October 2012	**155.4**/6.12	**7.4**	**30.2**/86.3	**23.8**/74.9
November 2012	**24.9**/0.98	**8.1**	**26.9**/80.5	**19.8**/67.7
December 2012	**58.9**/2.32	**7.6**	**26.9**/80.5	**19.8**/67.7
January 2013	**6.86**/0.27	**7.6**	**27.2**/81.0	**20.2**/68.4

Note: Monthly mean values have been rounded up to the nearest tenth

Statistical Analyses:

All experimental results were analysed using Instat+™ and ASSISTAT. Instat is an interactive statistical package, copyright © 2006, Statistical Services Centre, University of Reading, UK. All rights reserved. ASSISTAT, Version 7.6 beta (2013), website – http://www.assistat.com, by Fransisco de Assis Santos e Silva, Federal University of Campina-Grande City, Campina Grande, Brazil.

Results:

The six cassava varieties were described according to their leaf, stem and root morphological characteristics (Table 4), which distinguished them from one another. A wide range of variation was encountered in the characteristics of the cassava varieties in this study. Characteristics observed for three of the varieties evaluated during 2011 remained constant. Of the three new varieties evaluated, 'Honey Dew' was remarkably similar to 'Blue Mountain', being distinguished only by the colour of the immature apical leaves and the colour of the root cortex. The variety 'Fine Leaf' appeared to be very similar to 'John LaMotte', except for a few noticeable differences in the degree of leaf pubescence and the leaf petiole colour. The variety 'Haitian Stick' and 'Cuban White Stick' were the only varieties displaying a tan coloured root surface colour. Also, both of these varieties had the lowest numbers of storage roots per plant.

Table 4. Characteristics observed of six cassava varieties after 10 months of cultivation.

PLANT DATA	VARIETY					
	Blue Mountain	Cuban White Stick	Fine Leaf	Haitian Stick	Honey Dew	John LaMotte
Colour of first fully expanded leaf	green-purple	green-purple	dark green	light green	green-purple	dark green
Shape of central leaf lobe	elliptic	oblanceolate	linear	elliptic	elliptic	Linear
Colour of unexpanded apical leaves	green-purple	green-purple	dark green	light green	purple	green-purple
Pubescence of young leaves (newly formed in the transitional stage)	sparse	dense	sparse	sparse	sparse	Dense
Petiole colour	green-red	green-purple	red	green-red	red	green-purple
Stem colour (observed between 50-100 cm from ground level)	dark brown	silver	light brown	silver green	dark brown	light brown
Storage roots per plant	8	3	6	4	7	7
Storage root pulp colour (observed immediately after being cut open)	white	white	white	white	white	White
Storage root surface colour	dark brown	tan	dark brown	tan	dark brown	dark brown
Colour of outer surface of storage root cortex	pink	pink	white	cream	cream	Cream

The yields from the six cassava varieties showed significant differences in the number of marketable tubers per plant and marketable weights per plant, as indicated by the analysis of variance test performed on them (Table 5). Analysis of the data showed a statistical significance of 1% level of confidence for the number of marketable roots per plant and a 5% level of confidence for the marketable weights per plant.

Table 5. Analysis of variance (ANOVA) for number of marketable tubers and marketable tuber weights among six cassava varieties. Standard error is for each treatment mean. Error mean square has 35 df. *, ** and *** denote statistical significance at 5, 1 and 0.1% level of confidence, respectively. NS indicates differences between means not significant.

		--------------------Significance levels---------------------	
Source	df	**Number of marketable tubers/plant**	**Weight of marketable tubers/plant (kg)**
Varieties	5	**	*
Error	30		
Std. Err		0.2	0.1

Root yields were determined by the marketable weight and number of storage tubers produced per plant. Table 6 displays the mean root yield responses for the six cassava varieties. Total tuber yield for the varieties ranged from 1.27 kg per plant for 'Honey Dew' to 2.6 kg per plant for 'John LaMotte'. Of the six cassava varieties, 'Blue Mountain' and 'John LaMotte' had the highest number of marketable tubers per plant. 'Cuban White Stick' produced the lowest number of marketable tubers per plant, but had the highest weight for individual tubers.

Table 6. Mean values of root yield responses assessed 9 months after planting six cassava varieties.

Variety	Number of marketable tubers/plant	Weight of marketable tubers/plant (kg)
Blue Mountain	4.2a	1.72ab
Cuban White Stick	1.5b	1.33b
Fine Leaf Cassava	3.7a	2.23ab
Haitian Stick	2.2b	1.45b
Honey Dew	2.3b	1.27b
John LaMotte	4.0a	2.60a

The t-test at a level of 5% probability was applied. For each variety, means within columns bearing different lowercase letters differ significantly at 5% level of confidence.

Table 7 presents a summary of measurements for the proximate analyses of the raw pulp taken from freshly harvested roots of the six cassava varieties evaluated. The moisture contents for the six cassava varieties were very high, which make these cassava roots very susceptible to attack from microorganisms. Dry matter content ranged from 31.2% in ‘John LaMotte’ to 43.5% in ‘Cuban White Stick’. These values are similar to the range of values for cassava varieties as reported by several researchers (Chávez, *et al*., 2008; Ramanandam, *et al*., 2008; Teye, *et al*., 2011) who recorded values ranging from 29.8% to 40.7%, with an average of 34.5%.

Table 7. Proximate analyses of the raw pulp taken from the tubers of six cassava varieties.

VARIETY	ASH %	MOISTURE %	DRY MATTER %	PROTEIN %	FAT (CRUDE) %	SODIUM (MG/100G)	POTASSIUM (MG/100G)
Blue Mountain	3.00	63.29	36.71	2.10	0.20	30.89	1230.08
Cuban White Stick	2.27	56.50	43.50	1.20	0.41	22.27	817.26
Fine Leaf Cassava	2.65	62.92	37.08	1.23	0.41	29.70	1059.17
Haitian Stick	2.54	63.79	36.21	1.58	0.27	25.18	973.17
Honey Dew	3.24	65.21	34.79	1.92	0.27	28.74	1301.20
John LaMotte	3.00	68.80	31.20	1.93	0.23	34.87	1206.08

The fresh cassava pulp revealed low sodium contents and very high amounts of potassium, when compared to values stated in the literature for these minerals (Adepoju *et al*., 2010). The mean values of sodium (mg/100g), ranged from 22.3 to 34.9, while the values for potassium (mg/100g) ranged from 817.3 to 1301.2. These values compare favourably to those of Rojas *et al*. (2007), whose mineral contents of six cassava varieties averaged 623mg/100g for potassium and 30mg/100g for sodium.

The ash content varied from 2.3% for ‘Cuban White Stick’ to a high of 3.2% for ‘Honey Dew’. The percentage ash content, which gives an indication of the total mineral content of the six cassava varieties, is comparable to that of Odebunmi *et al.* (2007) and, more recently, Offor *et al*. (2012), who reported ash contents for cassava averaging 2.65% of dry matter. This low ash content is indicative of the low mineral content of cassava (Adepoju and Nwangwu, 2010).

The fat content of cassava is determined by age of plant when harvested, variety and environmental conditions, among other factors. The mean percentage of crude fat found within the fresh cassava pulp ranged from 0.20% to 0.41%. These results are much lower than the 0.74% to 1.49% reported by Emmanuel *et al*. (2012) for fresh cassava roots, but are within range of the 0.18% fat content obtained by Odebunmi *et al.* (2007) and the 0.45% results of Ibanga and Oladele (2008).

The percentage of protein for the raw pulp taken from the tubers of the six cassava varieties under examination are presented in Table 7. We see that the protein values ranged from 1.2% to 2.1%. These values are in agreement with those of Nassar and Dorea (1982), who reported 0.9 to 1.4% protein in peeled cassava tubers, and Emmanuel *et al.* (2012) whose investigation of six cassava varieties detected values ranging from 1.2 to 3.5%.

The total carbohydrate content of the six cassava varieties was calculated by difference, using the formula (FAO, 2003):

100 - (weight in grams [protein + fat + water + ash + alcohol] in 100 g of cassava).

The alcohol content was assumed to be negligible, as there was not expected to be any chemical conversion of sugars within the freshly harvested raw pulp. The total carbohydrate contents for the six cassava varieties are shown in Table 8.

Table 8. Total carbohydrate content of six cassava varieties, evaluated during 2013.

VARIETY	TOTAL CARBOHYDRATE %
Blue Mountain	31.41
Cuban White Stick	39.62
Fine Leaf Cassava	32.79
Haitian Stick	31.82
Honey Dew	29.36
John LaMotte	26.28

The cassava varieties were very high in their carbohydrate contents, compared to the other nutrients analysed in this study. The carbohydrate contents (Table 8) ranged from 26.3% to 39.6%, with an average content of 31.9%. 'John LaMotte' showed the lowest value, while the variety 'Cuban White Stick' had the highest carbohydrate content. These values are comparable to those of Adepoju and Nwangwu (2010), whose analysis of the nutrient composition of fresh cassava root revealed a carbohydrate content of 32.6%. In a recent cassava research trial (Richardson, 2011), the carbohydrate contents of the varieties 'Blue Mountain', 'Cuban White Stick' and 'John LaMotte' were, 42.7%, 40.6% and 37.6%, respectively. As the protein content was not analysed in that trial, the carbohydrate values were obtained using a fair estimate from the literature. This has resulted in carbohydrate values somewhat higher than the actual determinations of this present study.

Discussion:

The mean weight for each of the six cassava varieties was expressed as kg per plant. By extrapolation, the estimated yields of the cassava varieties ranged from 9.5 to 19.5 tonnes per hectare (Fig. 1), with 'John LaMotte' having the highest yield. The results indicate that the three best performers were superior in yield to the FAO estimates for cassava production and are well above the world average (FAOSTAT, 2011) of 12.8 tonnes per hectare. The other six varieties are within range of the FAO estimates, and with improved agronomic practices their yields could be increased.

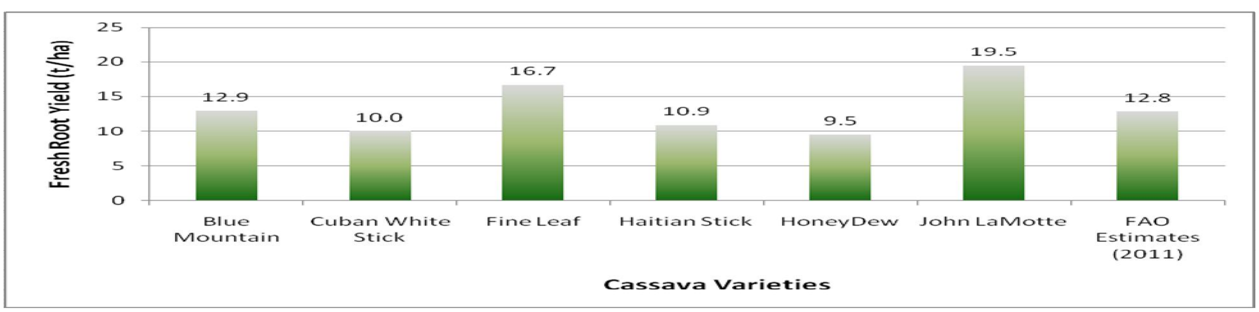

Fig. 1. Average fresh root yields of six cassava varieties evaluated at the Gladstone Road Agricultural Centre during 2013. FAO yield estimates for the cassava growing regions of the world in 2009 are found in the column at far right.

Analysis of the biochemical and mineral composition of the raw cassava pulp revealed that the cassava varieties were moderately rich in nutrients, with appreciable amounts of minerals. The carbohydrate contents of the six varieties were high, making them good energy sources. The results support their use as an important food source. The variety 'Cuban White Stick' displayed the lowest moisture content of the six cassava varieties. Cassava varieties with low moisture contents are more suitable for long-term storage of their roots than varieties with high moisture contents (Adejumo, 2012).

The minerals sodium and potassium were fairly evenly distributed in all of the cassava varieties; though 'Cuban White Stick' had mineral contents lower than the others. When comparing the contents of sodium and potassium (Table 7) with results found in the literature, the potassium values of this study were higher, while the sodium values were significantly lower. It is more than likely that these differences are due to the variety, age of the plant or the levels of these minerals in the soil. The percentage ash content, which gives an indication of the total mineral content of the six cassava varieties, is comparable to that of Wheatley *et al.* (1995) who reported ash contents of 0.5-1.5% of dry matter.

The low protein contents of the six cassava varieties corroborate the long held view that the protein content of cassava is very low (Nasser and Costa, 1978; Nassar and Dorea, 1982; Yeoh and Truong, 1996; Charles *et al.*, 2005; Ceballos *et al*., 2006; Sankaran *et al.*, 2008; Li *et al*., 2012), and are similar to the findings of these researchers. Ceballos *et al*. (2006) further suggest that the wide range of protein values found in their study (0.95% - 6.42%) were genetic in nature and provide excellent opportunities for the improvement of protein levels through conventional breeding methods.

The crude fat values for the raw pulp of the six cassava varieties were quite low when compared to those of other researchers (Rojas *et al*., 2007; Emmanuel *et al*., 2012). However, these results are within range of the fat content of cassava specified in the nutritional composition table of Bradbury and Holloway (1988). A diet providing 1-2% of its caloric of energy as fat is said to be sufficient to human beings, as excess fat consumption is implicated in certain cardiovascular disorders such as atherosclerosis, cancer and aging (Antia *et al*., 2006).

The six cassava varieties under evaluation all had appreciable levels of nutrient and chemical compositions, and can be recommended as a part of a nutritionally balanced diet. The low values reported in this study for protein and mineral content suggest that improvements can be made to enhance the nutritional value of this crop through varietal selection. These results are generally lower than the results of the previous trial at the Gladstone Road Agricultural Centre in which three cassava varieties were analysed for biochemical and mineral compositions. That trial was evaluated after ten months of growth, while the present trial was harvested after only nine months. Although this study disclosed much about the nutritional value of the six cassava varieties, much more work needs to be done on identifying the vitamins and other essential minerals of the cassava root, such as calcium, iron, magnesium and zinc.

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References:

Adejumo, B.A. (2012). Influence of initial moisture content on some proximate quality attributes of packaged gari in storage. *International Journal of Applied Biological Research* Vol. **4**(1&2): 32 - 38.

Adepoju, O.T., Adekola, Y.G., Mustapha, S.O. and Ogunola, S.I. (2010). Effect of processing methods on nutrient retention and contribution of cassava *(manihot spp)* to nutrient intake of Nigerian consumers. *Afr. J. Food Agric. Nutr. Dev*. **10**(2): 2099-2111.

Adepoju, O.T. and Nwangwu, J.O. (2010). Nutrient composition and contribution of noodles (*abacha*) and local salad from cassava *(Manihot spp)* to nutrient intake of Nigerian consumers. *African Journal of Food Science* Vol. **4**(7), pp. 422 – 426.

Antia, B.S., Akpan, E.J., Okon, E.A. and Umoren, I.U. (2006). Nutritive and anti nutritive of evaluation of sweet potatoes leaves. *Pakistan Journal of Nutrition* **5**, 166-168.

A. O. A. C. (1995). Official Methods of Analysis, 16th Edition. Association of Analytical Chemists, Washington, D. C.

Barratt, N., Chitundu, D., Dover, O., Elsinga1, J., Eriksson, S., Guma, L., Haggblade, M., Haggblade, S., Henn, T.O., Locke, F.R., O'Donnell, C., Smith, C. and Stevens, T. (2006). Cassava as drought insurance: Food security implications of cassava trials in Central Zambia. *Agrekon*, Vol **45**, No 1, 106-123.

Bioversity International, CIAT. (2009). Key access and utilization descriptors for cassava genetic resources. Bioversity International, Rome, Italy, International Center for Tropical Agriculture (CIAT), Cali, Colombia.

Bradbury, J.H. and Holloway, W.D. (1988). Cassava, *M. esculenta*. Chemistry of tropical root crops: significance for nutrition and agriculture in the Pacific. Australian Centre for International Agricultural Research, monograph nr 6, Canberra, Australia, pp. 76–104.

Buitrago, A.J.A. (1990). La yuca en la alimentación animal. Centro Internacional de Agricultura Tropical (CIAT), Cali, Colombia p. 446.

Cardoso, A.P., Mirione, E., Ernesto, M., Massaza, F., Cliff, J., Haque, M.R., Bradbury, J.H. (2005). Processing of cassava roots to remove cyanogens. *Journal of Food Composition and Analysis*, **18**, 451–460.

Ceballos, H., Iglesias, A.C., Perez, J.C. and Dixon, A. (2004). Cassava breeding: opportunities and challenges. *Plant. Mol. Biol*., **56**: 506–516.

Ceballos, H., Sánchez, T., Chávez, A.L., Iglesias, C.A., Debouck, D., Mafla, G. and Tohme, J. (2006). Variation in crude protein content in cassava (*Manihot esculenta* Crantz) roots. *J. Food Composition and Analysis*, **19**:589-593.

Charles, A.L., Sriroth, K. and Huang, T.C. (2005). Proximate composition, mineral contents, hydrogen cyanide and phytic acid of 5 cassava genotypes. *Food Chemistry* **92**: 615–20.

Chávez, A.L., Ceballos, H., Rodriguez-Amaya, D.B., Pérez, J.C., Sánchez, T., Calle, F., Morante, N. (2008). Sampling variation for carotenoids and dry matter contents in cassava roots. *Journal of Root Crops* **34**(1). 43-49.

Chávez, A. L., Sánchez, T., Jaramillo, G., Bedoya, J. M., Echeverry, J., Bolaños, E. A., Ceballos, H. and Iglesias, C. A. (2005). Variation of quality traits in cassava roots evaluated in landraces and improved clones. *Euphytica* **143**:125-133.

Emmanuel, O.A., Clement, A., Agnes, S.B., Chiwona-Karltun, L. and Drinah, B.N. (2012). Chemical composition and cyanogenic potential of traditional and high yielding CMD resistant cassava (*Manihot esculenta* Crantz) varieties. *International Food Research Journal* 19(1): 175-181.

Enidiok, S. E., Attah, L. E., & Otuechere, C. A. (2008). Evaluation of Moisture, Total Cyanide and Fiber Contents of Garri Produced from Cassava (*Manihot utilissima*) Varieties Obtained from Awassa in Southern Ethiopia. *Pakistan Journal of Nutrition* , **7**(5): 625-629.

FAO (Food and Agriculture Organization of the United Nations) Yearbook, (2007). Website: www.fao.org.

FAO (Food and Agriculture Organization of the United Nations) Food energy-methods of analysis and conversion factors. Rome, Italy, (2003). (FAO Food and Nutrition Paper no. 77) Website: www.fao.org.

FAOSTAT (2011). *Food and Agricultural Commodities Production*; Available online: http://faostat.fao.org (accessed 31 January, 2013).

Hershey, C., Henry, G., Best, R. and Iglesias, C. (1997). *Cassava in Latin America and the Caribbean*.

Ibanga, U.I. and Oladele, A.K. (2008). Production and determination of the proximate composition and consumer acceptability of an enriched dumpling (masovita) made of maize, soybeans and cassava. *Journal of Applied Biosciences*, Vol. **6**(2): 180 – 183.

Li, X., Yang, J., Manary, M. and Hirschi K.D. (2012). Biotechnologically-modified cassava: Protein absorption relative to casein. *J Bioequiv Availab.* **4**: 040-043.

Nassar, N.M.A. and Costa, C.P. (1978). Tuber formation and protein content in some wild cassava (mandioca) species native to Central Brasil. *Experientia(Basel)* **33**:1304-1306.

Nassar, N. M. A. and Dorea, G. (1982). Protein contents of cassava cultivars and its hybrid with Manihot species. Turrialba . *Turrialba* **32**: 429-432.

Neppl, G. P., Wehner, T. C. and Schulthers, J. R. (2003). Interaction of border and center rows of multiple row plants in watermelon yield trials. *Euphytica* **131**, N02.

Ntawuruhunga, P. and Dixon, A.G.O. (2010). Quantitative variation and interrelationship between factors influencing cassava yield. *Journal of Applied Biosciences*, **26**: 1594 - 1602.

Odebunmi, E.O., Oluwaniyi, O.O., Sanda, A.M. and Kolade, B.O. (2007). Nutritional compositions of selected tubers and root crops used in Nigerian food preparations. *International Jour. Chem*. Vol. **17**, No. 1, pp 37-43.

Offor, C.E., Igwenyi, I.O., Afiukwa, C.A., Uruaku, A.J., Aloh, G.S., Aja, P.M. and Onwe, F.I. (2012). The comparative proximate compositions of staple food crops in Ezzangbo (Ohaukwu L.G.A.) and Iboko (Izzi L.G.A) of Ebonyi State, Nigeria. *Continental J. Pharmacology and Toxicology Research* **5** (2): 23 – 27.

Okigbo, B.N. (1980). Nutritional implications of projects giving high priority to the production of staples of low nutritive quality. In the case for cassava (*Manihot esculenta*, Crantz) in the humid tropics of West Africa. Food and Nutrition Bulletin **2**, 1–10.

Ramanandam, G., Ravisankar, C. and Srihari, D. (2008). Integrated nutrient management for cassava under rainfed conditions of Andhra Pradesh. *Journal of Root Crops*, Vol. **34**, No. 2, pp. 129-136.

Richardson, K.V. (2011). Evaluation of three cassava varieties for tuber quality and yield. *GRAC Crop Research Report* No.**4**, Department of Agriculture, Nassau, Bahamas.

Rojas, C. C., Nair, B., Herbas, A. and Björn Bergenståhl, B. (2007). Proximal composition and mineral contents of six varieties of cassava (*Manihot esculenta* Crantz), from Bolivia. *Rev. Bol. Quim*, vol.**24**, no.1, p.71-77.

Romani, M., Borghi, B., Albercici, R., Delogu, G., Hesselbach, J. and Sclami, F. (1993). Intergenotypic competition and border effect in bread wheat and barley. *Euphytica* **69**, 1-2.

Salcedo, A., Valle, A.D., Sanchez, B., Ocasio, V., Ortiz, A., Marquez, P., Siritunga, D. (2010). Comparative evaluation of physiological post-harvest root deterioration of 25 cassava (*Manihot esculenta*) accessions: visual vs. hydroxycoumarins fluorescent accumulation analysis. *African Journal of Agricultural Research* **5**: 3138-3144.

Sankaran, M., Singh, N. P., Chander D., Santhosh, B., Nedunchezhiyan, M., Naskar, S. K. and Ngachan, S. V. (2008). Evaluation of high yielding cassava varieties under upland conditions of Tripura. *Journal of Root Crops*, Vol. **34**, No. 1, pp. 73-76.

Siritunga, D.; Sayre, R. (2004). Engineering cyanogen synthesis and turnover in cassava (*Manihot esculenta*). *Plant Mol. Biol.*, **56**, 661-669.

Teye E., Asare A. P., Amoah R. S. and Tetteh J. P. (2011). Determination of the dry matter content of cassava (*Manihot esculenta*, Crantz) tubers. *ARPN Journal of Agricultural and Biological Science*. Vol. **6**, No. 11, pp. 23-28.

Tonukari, N.J. (2004). Cassava and the future of starch**.** *Electronic Journal of Biotechnology*, **7**(1): 5-8.

Weatley, C., Scott, G., Best, R. and Weirsema S. (1995). Adding value to root and tuber crops: a manual on product development. The International Centre for Tropical Agriculture (CIAT publication, no.247, 166p), Cali, Colombia.

Wilson, W.M. and Dufour, D.L. **(**2002). Why "bitter" cassava? The productivity of "bitter" and "sweet" cassava in a Tukanoan Indian settlement in the Northwest Amazon. *Economic Botany* **56**(1): 49-57.

Yeoh, H.H. and Truong, V.D. (1996). Protein contents, amino acid compositions and nitrogen-to-protein conversion factors for cassava roots. *J. Sci. Food Agric.*, **70**, 51-54.