International Food Research Journal 19(1): 175-181 (2012)

Chemical composition and cyanogenic potential of traditional and high yielding CMD resistant cassava (*Manihot esculenta* Crantz) varieties

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Abstract: High yielding cassava mosaic disease (CMD) resistant cassava varieties have been developed by the Crop Research Institute of Ghana with distinct chemical composition and cyanogenic glucoside concentrations. This study characterized these improved varieties (Ampong, Broni bankye, Sika and Otuhia) together with some traditional varieties (Amakuma and Bankye fitaa) for their nutritional properties and cyanogenic potential (toxicity). The proximate composition, mineral content and cyanogenic potential were determined using standard methods. The different cultivars had moisture content (33.14-45.86%), protein (1.17–3.48%), ash (1.71–2.34%), crude fibre (1.38-3.20%), fat (0.74-1.49%) and carbohydrate (83.42-87.35%) and these varied significantly among cultivars. Mineral contents were 0.60-1.60, 1.35-1.58 and 1.06-2.13 mg/100g for Ca, Mg and P respectively, and 0.16-0.24, 0.021-0.030, 0.04-0.13, 0.25-0.36 and 0.25-0.37 mg/100g for Fe, Mn, Zn, K and Na respectively. Cyanogenic potential ranged from 0.08-0.12 mgHCN/kg. Wide variations exist in chemical composition of the improved and traditional cassava cultivars but all possess safe levels of cyanogenic potential and thus safe for human consumption.

Keywords: Cassava, chemical composition, mineral content, nutrients, cyanide, cyanogenic potential, cluster analysis

Introduction

Cassava (*Manihot esculenta* Crantz) has been identified to provide food security for Africa. In Ghana, in terms of root crop production and yield, it is ranked first followed by yam and cocoyam where it stands as a source for industrial raw material and income for rural communities. In 2008, 47% of the volume of major crops produced in Ghana was cassava, with bulk of it from the middle and southern parts of the country (Janick, 2011). The roots of the cassava plant are the main storage organ which has three distinct tissues: bark (periderm), peel (cortex), and parenchyma. Okigbo (1980) reported that the calorific value of cassava is high compared to most staples. Cassava grown by nearly every farming family can be said to account for the daily calorie intake in Ghana. Currently, different cassava cultivars are processed into various intermediate and finished food products including high quality cassava flour (HQCF), cassava dough (agbelima), starch, gari, chips and instant fufu flours on the large scale. Other products such as glucose and high fructose syrups and other beverages are being introduced based on the starch and amylose contents of the varieties (Aryee *et al*., 2006).

Cassava roots and leaves which constitute 50% and 6% of the mature plant, respectively, are the nutritionally valuable parts of the plant (Tewe and Lutaladio, 2004). The nutritional value of the roots is important because they are the main part of the plant consumed in developing countries. The edible starchy flesh comprises some 80% to 90% total weight of the root with water forming the major components (Wheatley *et al*., 1993; Harris and Koomson, 2011). The water content for cassava is between the range of 60.3% to 87.1% (Padonou *et al*., 2005; Zvinavashe *et al*., 2011) whilst moisture content for cassava flour varies from 9.2% to 12.3% (Charles *et al*., 2005) and 11% to 16.5% (Shittu *et al*., 2007). Water is an important parameter in the storage of cassava flour; very high levels greater than 12% allow for microbial growth and thus low levels are favourable and give relatively longer shelf life (Padonou *et al*., 2010; Harris and Koomson, 2011).

Cassava contains about 1-2% protein which makes it a predominantly starchy food (Charles *et a*l., 2005). The protein content is low at 1% to 3% on a dry matter basis (Buitrago, 1990) and between 0.4 and 1.5 g/100 g fresh weight (Bradbury and Holloway, 1988). In contrast, maize and sorghum have about 10 g protein/100 g fresh weights (Montagnac, 2009). As human food, it has been criticized for its low and poor quality protein content, but the plant produces more

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weight of carbohydrate per unit area than other staple food crop under comparable agro-climatic conditions. About 50% of the crude protein in the roots consists of whole protein and the other 50% is free amino acids (predominantly glutamic and aspartic acids) and non-protein components such as nitrite, nitrate and cyanogenic compounds (Zvinavashe *et al*., 2011).

Cassava is an energy-dense food and therefore ranked high for its calorific value of 250 x 10^3 cal/ha/day as compared to 176 x 10^3 for rice, 110 x 10^3 for wheat, 200 x 10^3 for maize, and 114 x 10^3 for sorghum (Okigbo, 1980; Jisha *et al*., 2010). The root is a physiological energy reserve with high carbohydrate content, which ranges from 32% to 35% on a fresh weight (FW) basis, and from 80% to 90% on a dry matter (DM) basis (Montagnac, 2009; Zvinavashe *et al*., 2011). Raw cassava root has more carbohydrate than potatoes and less carbohydrate than wheat, rice, yellow corn, and sorghum on a 100 g basis (Montagnac, 2009). The lipid content in cassava roots ranges from 0.1% to 0.3% on a fresh weight basis with ranges at 0.1% to 0.4% (Charles *et al*., 2005) and 0.65% (Padonou *et al*., 2005) on a dry weight basis. This content is relatively low compared to maize and sorghum, but higher than potato and comparable to rice. The lipids are either non-polar (45%) or contain different types of glycolipids (52%) (Hudson and Ogunsua, 1974). The glycolipids are mainly galactose-diglyceride (Gil and Buitrago, 2002). The predominant fatty acids are palmitate and oleate (Hudson and Ogunsua, 1974).

Cyanide is the most toxic factor restricting the consumption of cassava roots and leaves. There are three different forms of cyanogens present in cassava root and leaves and these include linamarin, acetonehydrin (lotaustralin) and free HCN. The linamarin and lotaustralin undergo a sequential enzymatic breakdown and the final form is a toxic free cyanide. The total of these three forms is called Cyanogenic potential. Cyanogenic glycosides are effective defence agents against generalist herbivores (Gleadow *et al*., 2002), including humans. Cassava leaves have a cyanide content ranging from 53 to 1,300 mg cyanide equivalents/kg of DW (Siritunga and Sayre, 2003; Wobeto *et al*., 2007), and cassava root parenchyma has a range of 10 to 500 mg cyanide equivalents/kg dry matter (Arguedas *et al*., 1982; Siritunga and Sayre, 2003); both of these are much higher than what is recommended. Bitter cassava varieties, have cyanide levels higher than the FAO/WHO (1991) recommendations, which is < 10 mg cyanide equivalents/kg DM, to prevent acute toxicity in humans. Yeoh and Sun (2001) reported 15–61 mg HCN/kg in various food products containing cassava flours. Several health disorders and diseases have been reported in cassava-eating populations. Consumption of 50 to 100 mg of cyanide has been associated with acute poisoning and has been reported to be lethal in adults (Yeoh and Sun, 2001). The consumption of lower cyanide amounts are not lethal but long-term intake could cause severe health problems such as tropical neuropathy, glucose intolerance, and, when combined with low iodine intake, goiter and cretinism (Delange *et al*., 1994; Harris and Koomson, 2011).

Variety plays a very important role in the production of diversified food products due to inherent characteristics which vary from one cassava to the other (Safo-Kantanka and Owusu-Nipah, 1992; Jisha *et al*., 2010; Zhang *et al*., 2010). Such characteristics include amylose, starch content, cyanide, whiteness and sweetness, even though a local producer would consider high yield, early maturation and tuber size to determine the type of variety to produce for the market. In Ghana, some of the traditional cassava varieties grown extensively across the country include Ankra, Bankye kokoo, Bankye fitaa and Bosumensia. However, in recent times, new and improved cultivars - high yielding and Cassava Mosaic Disease (CMD) resistance have been developed through collaboration by International Institute for Tropical Agriculture (IITA) and Crops Research Institute in Ghana with distinct nutritional, physiological, structural and biochemical constitution. Some of these include Ampong, Broni Bankye, Sika and Otuhia. This study sought to characterize these different traditional and improved cassava varieties for their varied chemical composition, mineral content and cyanogenic glucoside levels.

Materials and Methods

Cassava samples

Six varieties of cassava made up of four improved varieties and two traditional varieties obtained from the experimental fields of the Crop Research Institute of Council for Scientific And Industrial Research (CSIR) situated at Pokuase in the Greater Accra Region of Ghana were used in the study. Table 1 gives the description of the varieties.

Table 1. Variety, type, age and source of samples

Sample	Type	Age at harvest (months)	Source
Ampong-CSIR	Improved	12	Crops Research Institute, Pokuase
Broni bankye-CSIR	Improved	12	Crops Research Institute, Pokuase
Sika-CSIR	Improved	12	Crops Research Institute, Pokuase
Otuhia-CSIR	Improved	12	Crops Research Institute, Pokuase
Amakuma	Traditional	12	Crops Research Institute, Pokuase
Bankye fitaa	Traditional	12	Crops Research Institute, Pokuase

Sample preparation

The samples were harvested from the fields of Crop Research Institute, Pokuase in the Greater Accra Region of Ghana and transported immediately to the laboratory. At the laboratory, the samples were cleaned, peeled and washed with potable water. Samples from the distal, middle and apical sections of peeled tubers were cut into cube and oven dried at 60^{o}C for 48 h. The oven dried samples were ground in a Hammer mill (Christy and Norris Ltd., Chelmsford, Surrey, UK) into flour to pass through a 250-mm sieve. The flour samples obtained were then packaged into polypropylene bags and kept at room temperature (25-28^{o}C) for analyses.

Proximate analyses

The moisture, crude protein (N x 6.25), fat, ash and crude fibre contents were determined by Association of Official Analytical Chemists' Approved methods 925.10, 920.87, 920.85, 923.03 and 963.09 respectively (AOAC, 2005). Carbohydrate content was determined by difference. The energy content of the tubers was determined by multiplying the percentages of crude protein, crude lipid, and carbohydrates by the factors 16.7, 37.7 and 16.7, respectively (Montagnac *et al*., 2009).

Mineral analyses

Phosphorus and calcium levels were evaluated by the Association of Official Analytical Chemists' Approved methods 948.09 and 944.03 respectively (AOAC, 2005). Iron contents were also determined by the AOAC ortho-phenanthroline method 944.02 (AOAC, 2005). Flame photometry was used for Na and K and Atomic Absorption Spectrometry (AAS) for the remaining minerals studied.

Cyanide determination

The acid titration method (AOAC, 2005) for the determination of hydrocyanic acid in beans was used. One hundred (100) millilitres of H_2O was added to 3 g of the sample in a 500 ml Kjedahl flask for steam distillation. The distillate was collected in 20 ml 0.02N $AgNO_3$ acidified with 1 ml HNO_3. The apparatus was adjusted so that the tip of the condenser dipped below surface of the liquid in the receiver. After 150 ml had passed over, excess $AgNO_3$ was titrated with 0.02 KSCN using Fe alum as indicator. The results were calculated and reported as mean values on dry matter basis.

Statistical analysis

Statistical analysis and graphical presentation were done using Minitab (version 14) and Microsoft Excel (2007 version) respectively. Analysis of variance for the cassava varieties was conducted at a level of significance of $p<0.05$. Cluster Analysis (cluster observation) was carried out to group cassava varieties with similar characteristics. Principal component analysis (PCA) was used to ascertain patterns and explore the relationships between the various parameters and the cassava samples.

Results and Discussion

Proximate composition of improved and traditional cassava varieties

The proximate composition of the cassava varieties is shown in Table 2. Variations in the water content of the fresh roots (improved and traditional varieties) were observed with values ranging from 33.14% to 45.86% (wb) with Bankye fitaa having the lowest and Broni bankye the highest respectively. Significant differences ($p\leq0.05$) existed amongst the varieties. The observed ranges were below those (65 - 74% wb) reported by Wheatley and Chuzel (1993) on four cultivars harvested at various ages and seasons, and those of 60.3% to 87.1% reported by Padonou *et al*. (2005).

Varieties with low moisture content would be suitable for prolonged root storage (Trèche *et al*., 1995). On dry basis, moisture ranged between 7.48% to 9.66% which were low relative to values of 9.2% to 12.3% and 11% to 16.5% reported by Charles *et al*. (2005) and Shittu *et al*. (2007) respectively. Two of the samples, Amakuma (9.40%) and Bankye fitaa (9.66%) were within the ranges previously reported. Moisture is an important parameter in the storage of cassava flour; very high levels greater than 12% allow for microbial growth and thus low levels are favourable and give relatively longer shelf life. All the samples had good moisture levels and hence have the potential for better shelf life.

The crude protein content of the six varieties investigated ranged from 1.17% (Broni Bankye) to 3.48% (Bankye fitaa) (Table 2). There was a significant difference amongst the studied variety and this may be attributed to varietal differences. These low protein levels were expected because protein content of cassava ranging between 1% to 3% on a dry matter basis was reported by Buitrago (1990) with fresh weight content between 0.4 and 1.5 g/100 g (Bradbury and Holloway, 1988). The ash content of the cassava flour samples ranged from 1.71% to 2.34% with Broni bankye having the lowest and Otuhia the highest respectively (Table 2). Significant differences ($p<0.05$) existed in the ash content of the cassava varieties. Values obtained were comparable

Table 2. Proximate composition of traditional and improved cassava varieties

Variety	Moisture (FW) %	Moisture* (%)	Protein* (%)	Ash* (%)	Fat* (%)	Crude Fibre* (%)	Carbohydrate* (%)	Energy (kJ100 g-1DM)
Ampong[1]	38.97±1.61[b]	7.76±0.85[a]	1.71±0.57[b]	2.00±0.07[b]	1.49±0.90[b]	1.56±0.23[a]	87.17±0.90[b]	1541
Broni Bankye[1]	45.86±2.10[c]	8.55±0.50[a,b]	1.17±0.32[a]	1.71±0.16[a]	1.08±0.38[a,b]	1.38±0.12[a]	87.12±0.65[b]	1515
Sika[1]	36.25±5.94[b]	7.48±0.50[a]	1.60±0.36[b]	2.23±0.16[c,d]	1.41±0.58[b]	1.88±0.24[a]	87.05±1.18[b]	1534
Otuhia[1]	44.36±2.63[c]	7.65±0.76[a]	1.79±0.44[b]	2.34±0.15[d]	1.16±0.41[a,b]	1.90±0.47[a]	87.35±0.55[b]	1532
Amakuma[2]	44.49±3.01[c]	9.40±0.48[b]	2.93±0.45[c]	2.26±0.24[c,d]	0.74±0.27[a]	2.22±0.63[a]	84.67±0.81[a]	1491
Bankye fitaa[2]	33.14±1.70[a]	9.66±0.48[b]	3.48±0.47[d]	2.13±0.11[b,c]	1.07±0.20[a,b]	3.20±2.39[b]	83.42±0.52[a]	1492

In each column means followed by different letters (a, b, c, etc.) are significantly different at $p < 0.05$
[1] improved variety and 2 traditional variety
FW – values reported on fresh weight basis
* - values reported in dry weight basis

to the range of 1% to 2.84% dry weight reported by Aryee *et al*. (2006). All the cassava varieties had low fat content with the highest being 1.49% (Ampong). However, the values were higher than those of 0.1% to 0.4% reported by Charles *et al*. (2005) and 0.65% reported by Padonou *et al*. (2005). There were no significantly differences (p<0.05) in the fat content amongst the studied cassava varieties.

Crude fibre ranged between the minimum value of 1.38% for Broni Bankye and the maximum value of 3.2% for Bankye fitaa. These values were higher than 1.10% (Buitrago, 1990) and 1.4% (Bradbury and Holloway, 1988) for cassava root, but lower than sweet cassava (10.31%) and comparable with bitter cassava (3.09%) (Okigbo, 1980). Significant difference existed except for the varieties Ampong, Broni bankye, Sika, Otuhia and Amakuma. Usually fibre content does not exceed 1.5% in fresh root and 4% in root flour (Gil and Buitrago, 2002). Carbohydrate values ranged from 83.42% (for Bankye fitaa) to 87.35% (for Otuhia). There were significant (p < 0.05) variations in the carbohydrate content of the varieties. These carbohydrate values presented were consistent with the range of 80% to 90% as reported by Montagnac *et al*. (2009). Energy content ranged from 1491 kJ 100g^{-1} DM (for Amakuma) to 1541 kJ 100g^{-1} DM (for Ampong) (Table 2). These results were slightly higher than the values of 1406 to 1465 kJ/100g DM as reported by Charles *et al*. (2005). The high energy and carbohydrate values obtained in this study suggest that cassava could be utilized as a reliable food and energy security crop as proposed by FAO (2008); especially owing to their content of some of the most desirable nutritional compounds like carbohydrate, fat, protein and minerals.

Minerals and cyanogenic potential of cassava varieties

The mineral content of the cassava varieties studied are shown in Table 3. Calcium content ranged from 0.06 to 1.60 mg/100g, with Sika being the highest and Otuhia the lowest (Table 3). All varieties showed significant (p<0.05) variability in calcium. Values obtained in this study were considerably lower than the reported values of 10 mg/100 g fresh weight basis (Buitrago, 1990), 33 mg/100 g fresh weight basis (Okigbo, 1980), 20 mg/100 g fresh weight basis (Bradbury and Holloway, 1988) and 136-369 mg/100g dry weight basis (Charles *et al*., 2005). Sodium ranged from 0.25 mg/100g (Broni bankye) to 0.37 mg/100g (Amakuma). The varieties differed significantly at p<0.05. The sodium contents obtained were lower than the reported values 7.6 mg/100g fresh weight basis (Buitrago, 1990) and 50 mg /100g (Charles *et al*., 2005).

Magnesium ranged from 1.35 mg/100g to 2.52 mg/100g with Bankye fitaa being the highest. However, all the varieties were not significantly different (p>0.05) in their Mg contents except for Bankye fitaa. Values obtained for magnesium content were lower as compared to reported values from published data which include 30 mg/100 g mg fresh weight (Bradbury *et al*.,1988; Buitrago, 1990) and 43 mg/100g dry weight (Charles et al., 2005). As well, K ranged from 0.25 to 0.36 mg/100g (Table 3). The data indicated that all the varieties were significantly different (p<0.05) with the results obtained generally lower than the reported ranges of 324 to 554 mg /100g dry weight basis (Charles et al., 2005), 250 mg/100g fresh weight (Buitrago, 1990) and 302 mg/100g fresh weight basis (Bradbury *et al*., 1988).

The iron content ranged from 0.16 to 0.24 mg/100g, which was markedly lower than the values reported on a fresh weight basis by Bradbury and Holloway (1988) (0.23 mg/100g), 0.7 mg/100g (Okigbo, 1980), 1.7 mg/100g Buitrago (1990) and 29 to 40 mg /100g on dry weight basis (Charles et al., 2005). Zinc content ranged from 0.04 to 0.05 mg/100g.

Table 3. Mineral content of traditional and improved cassava varieties

Variety	K (mg/100g)	Na (mg/100g)	Ca (mg/100g)	Mg (mg/100g)	P (mg/100g)	Fe (mg/100g)	Mn (mg/100g)	Zn (mg/100g)
Ampong[1]	0.30 ± 0.01^{b}	$0.28 \pm 0.03^{a,b}$	1.04 ± 0.20^{b}	1.35 ± 0.10^{a}	1.21 ± 0.00^{a}	0.19 ± 0.00^{d}	0.021 ± 0.00^{a}	0.05 ± 0.00^{b}
Broni Bankye[1]	0.25 ± 0.03^{a}	0.25 ± 0.04^{a}	0.91 ± 0.14^{b}	1.42 ± 0.33^{a}	1.06 ± 0.00^{b}	0.17 ± 0.00^{b}	0.030 ± 0.00^{c}	0.05 ± 0.00^{b}
Sika[1]	$0.33 \pm 0.04^{b,c}$	$0.32 \pm 0.02^{b,c}$	1.60 ± 0.17^{c}	1.42 ± 0.07^{a}	1.34 ± 0.00^{c}	0.18 ± 0.00^{c}	0.030 ± 0.00^{c}	0.09 ± 0.00^{d}
Otuhia[1]	0.35 ± 0.02^{c}	0.36 ± 0.02^{c}	0.60 ± 0.13^{a}	1.58 ± 0.21^{a}	1.61 ± 0.01^{d}	0.17 ± 0.00^{b}	0.023 ± 0.00^{b}	0.13 ± 0.00^{e}
Amakuma[2]	0.36 ± 0.03^{c}	0.37 ± 0.06^{c}	0.65 ± 0.05^{a}	1.49 ± 0.03^{a}	2.13 ± 0.00^{e}	0.24 ± 0.00^{e}	0.024 ± 0.00^{b}	0.08 ± 0.00^{c}
Bankye fitaa[2]	0.31 ± 0.02^{b}	$0.33 \pm 0.01^{b,c}$	1.12 ± 0.05^{b}	2.52 ± 0.12^{b}	1.26 ± 0.01^{f}	0.16 ± 0.00^{a}	0.021 ± 0.00^{a}	0.04 ± 0.00^{a}

In each column means followed by different letters (a, b, c, etc.) are significantly different at $p < 0.05$
[1] improved variety and 2 traditional variety

All varieties were significantly different at $p < 0.05$. However, the new varieties Ampong and Broni bankye had the same Zn contents (0.05 mg/100g) and were significantly different from the remaining cassava varieties. Buitrago (1990) reported 1.4 mg/100g (fresh weight basis) for Zn in cassava root tubers. Charles *et al*. (2005) reported 13 to 19 mg/100g dry weight basis for Zn from cassava flours.

Manganese was found to be the lowest mineral in cassava, with values ranging from 0.021 mg/100g to 0.03 mg/100g (Table 3). All the varieties showed significant differences at $p<0.05$. Charles *et al*. (2005) reported ranges between 0.31 to 3.54 mg/100g for cassava flours whilst Buitrago (1990) reported 0.3 mg/100g for Mn content of cassava root tubers. Phosphorus, which was one of the major minerals identified had the highest value in Amakuma (2.13 mg/100g) and the lowest in Broni bankye (1.06 mg/100g) and there were significant differences amongst the varieties at $p<0.05$. The values obtained where higher than those of 0.15 mg/100g fresh weight basis reported by Buitrago (1990) and lower than 153 mg/100g reported by Charles *et al*. (2005) on other cassava varieties.

The cyanogenic potential (CNp) ranged from 0.08 to 0.12 mg HCN/kg dry weight (Table 4). Otuhia had the lowest value while Sika had the highest. Analysis on the data showed that significant differences ($p<0.05$) existed in the cyanogenic potential of the different cassava varieties studied. All the varieties had their cyanide level lower than the FAO/WHO (1991) recommendation, which is <10 mg cyanide equivalents/kg DM, to prevent acute toxicity in humans. The values obtained were also far below that of previously published data which stated that cassava root parenchyma has a range of 10 to 500 mg cyanide equivalents/kg dry matter (Arguedas *et al*., 1982; Dufour 1988; Siritunga and Sayre 2003) and 15–61 mg HCN/kg (Yeoh and Sun, 2001) in various food products containing cassava flours.

Table 4. Cyanogenic potential of traditional and improved cassava varieties

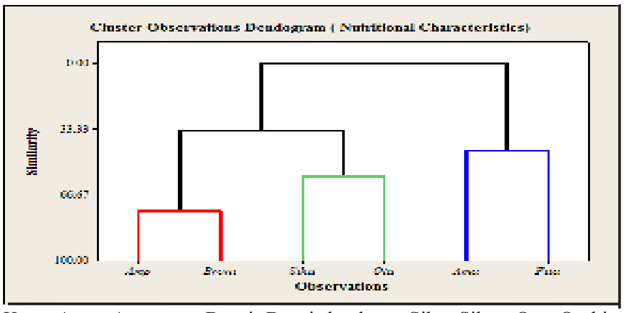
Variety	CNp (mgHCN/kg)
Ampong[1]	$0.10 \pm 0.00^{a,b}$
Broni Bankye[1]	$0.10 \pm 0.02^{a,b}$
Sika[1]	0.12 ± 0.01^{b}
Otuhia[1]	0.08 ± 0.00^{a}
Amakuma[2]	0.09 ± 0.01^{a}
Bankye fitaa[2]	0.09 ± 0.02^{a}

In each column means followed by different letters (a, b, c, etc.) are significantly different at $p < 0.05$
[1] improved variety and 2 traditional variety

Cluster and principal component analysis for nutritional characteristics of cassava varieties

Cluster and principal component analysis were applied to the nutritional characteristics of the cassava samples. These were done by grouping cassava varieties with similar characteristics to display pattern and interrelationship between the samples and their nutritional properties. Figure 1 shows the cluster observations dendogram for nutritional characteristics of the cassava varieties. This partitioned the samples into three clusters based on similarity of their characteristics. The two improved varieties (Ampong and Broni bankye) formed the first cluster. Sika and Otuhia also improved varieties were in the second cluster whilst Amakuma and Bankye fitaa both traditional varieties constituted the third cluster. Similarity between varieties was divided along improved and traditional lines. Among the improved varieties Ampong was similar to Broni bankye whilst Otuhia was also similar to Sika, leaving the local varieties in one cluster (Figure 1).

Principal component analysis applied to the nutritional characteristics of the cassava varieties showed that two components explained a total of 71.6% of the total variability in the data. PC1 accounted for 44.3% of the total variation in the nutritional characteristics while PC2 explained



Key: Amp=Ampong, Broni=Broni bankye, Sika=Sika, Otu=Otuhia, Ama=Amakuma, Fita=Bankye fitaa

Figure 1. Cluster observation dendogram for nutritional characteristics of traditional and improved cassava varieties

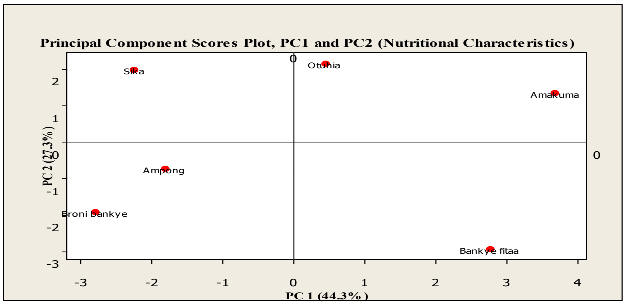
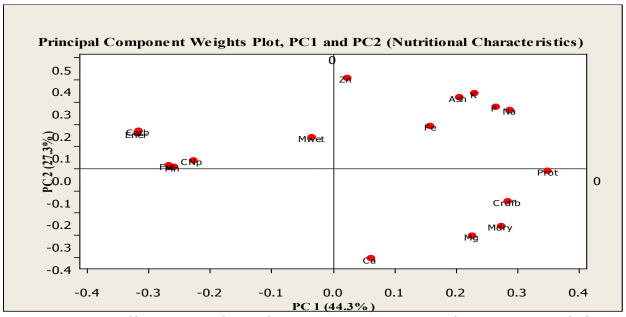


Figure 2. Sample scores of plot for the principal component analysis of nutritional characteristics of traditional and improved cassava varieties



Key: Na=Sodium, P=Phosphorus, Mg=Magnesium, Ca=Calcium, Prot=Protein, Fe=Iron, Ash=Ash, K=Potassium, Zn=Zinc, Crdfb=Crude fibre, Carb= Carbohydrate, Ener=Energy, Fat=Fat, Mn=Manganese, CNp=Cyanogenic potential, Mwet=Water content

Figure 3. Variable weights plot for the principal component analysis of nutritional characteristics of traditional and improved cassava varieties

27.3% (Figures 2 and 3). The sample score explained the portioning observed in the cluster analysis. All the traditional varieties were found loaded to the positive side while the improved varieties were found loaded to the negative side of PC1 except for Otuhia which had distanced itself in the positive side. The variable weights plot (Figure 3) showed a loading of most of the minerals, protein, crude fibre and ash close to each other on the positive side of the x-axis (PC1); which is related to the loading of the local varieties on the sample scores plot. This suggests that the traditional cassava varieties are different from the improved varieties on their nutritional level based on their higher ash, minerals, protein and crude fibre. The traditional varieties (Amakuma and Bankye fitaa) had higher levels of Fe, Na, Mg, Ca, P, K, Zn, ash, protein and crude fibre. Otuhia was found in the positive side because it had high levels of protein, crude fibre and Zn than the other new varieties. One characteristic feature which was common to Otuhia and the local varieties was that they all had low cyanide contents and high protein content. The new varieties differentiated themselves by having high levels of carbohydrate, energy, fat, cyanide and water content, probably due to soil and inherent factors peculiar to each variety.

The improved varieties were significantly different from the traditional varieties on the nutritional level. Among the improved varieties, Otuhia was different from the rest having high levels of Zn, protein and low cyanide content. Bankye fitaa (local variety) also distinguished itself from the other traditional variety because it had high levels of protein, ash, minerals, crude fibre but low water content. The low water content exhibited by Bankye fitaa means it has a high dry matter which is reflected in its high crude fibre, this makes it suitable for prolonged storage. The improved varieties having high carbohydrates mean they have high starch or sugar content.

Conclusion

All the studied cassava varieties had appreciable levels of nutritional composition even though the traditional varieties (Amakuma and Bankye fitaa) were similar in their levels of ash, minerals, protein and high dry matter content whilst the improved varieties (Ampong, Broni bankye, Sika and Otuhia) were peculiar in terms of their high carbohydrate and energy content. The studied cassava varieties had low cyanide levels which were all below the WHO/FAO recommendations (<10 mg cyanide equivalents/kg DM) and thus could all be safely recommended for consumption without acute toxicity to humans.

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