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EVALUATION OF TIGERNUT ACCESSIONS IN GHANA FOR PROXIMATE AND MINERAL COMPOSITION

E.F. DONKOR, D. NYADANU[1] and H.K. DAPAAH

University of Energy and Natural Resources, Department of Horticulture and Crop Production, Sunyani, Ghana
[1]Cocoa Research Institute of Ghana, Tafo, Koforidua, Eastern Region, Ghana
Corresponding author: esther.donkor@uenr.edu.gh

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ABSTRACT

Tigernut (*Cyperus esculentus* L.) is a nutritious, yet underutilised crop in Ghana. The objective of this study was to characterise Ghanaian tigernut accessions for proximate and mineral composition, as a guide for breeders for varietal development. Field and laboratory studies were conducted on 24 tigernut accessions from major growing areas of Ghana. The accessions were cultivated during the minor the growing season (September - November), at the Multipurpose Nursery of the University of Education, Winneba, Asante Mampong in Ghana. The nuts were analysed for proximate (carbohydrate, energy, moisture, ether extract, crude fiber, crude protein and ash) and mineral (potassium, phosphorus and calcium) composition. There were significant (P<0.05) differences among accessions for all traits studied. Accessions were clustered in a dendrogram by colour and geographical origin and PC1 and PC2 explained more than 80% of the total variations among the accessions, with carbohydrate and energy being the major contributors to the total variation. Accessions DY, BKB, KAB, TPY, CCY, WY2 and WY1, which recorded high levels of proximate and mineral compositions, may be considered for breeding programmes to provide high nutrient varieties of tigernut in Ghana.

Key Words: Carbohydrate, cluster analysis, *Cyperus esculentus*

RÉSUMÉ

Le Tigernut (*Cyperus esculentus* L.) est une culture nutritive mais sous-utilisée au Ghana. L'objectif de cette étude était de caractériser les accessions de souchet Ghanéen pour leur composition immédiate et minérale, comme un guide pour les sélectionneurs pour le développement variétal. Des études sur le terrain et en laboratoire ont été menées sur 24 accessions de souchet provenant des principales zones de culture du Ghana. Les accessions ont été cultivées pendant la petite saison de croissance (Septembre - Novembre), à la pépinière polyvalente de l'Université de l'éducation, Winneba, Asante Mampong au Ghana. Les noix ont été analysées pour leur composition proche (glucides, énergie, humidité, extrait d'éther, fibres brutes, protéines brutes et cendres) et composition minérale (potassium, phosphore et calcium). Il y avait des différences significatives (P <0,05) entre les accessions pour tous les caractères étudiés. Les accessions ont été regroupées dans un dendrogramme par couleur et origine géographique et PC1 et PC2 expliquaient plus de 80% des variations totales entre les accessions, les glucides et l'énergie étant les principaux contributeurs à la variation totale. Les accessions DY, BKB, KAB, TPY, CCY, WY2 et WY1, qui ont enregistré des niveaux élevés de composition proximale et minérale, peuvent être envisagées pour des programmes de sélection afin de fournir des variétés riches en nutriments de tigernut au Ghana.

Mots Clés: Glucides, l'analyse par grappes, *Cyperus esculentus*

INTRODUCTION

Tigernut (*Cyperus esculentus* L) is one of the underutilised crops in Ghana, which is associated with dismal levels of research. It belongs to the *cyperacea* family and produces edible, highly nutritious and medicinal tubers (Cortes *et al*., 2005). Typically, 100 g of the nuts contain 386 kcal (1635 kj) of energy, 7% proteins, 26% fats (oils), 31% starch, 21% glucose and 26% fibre (Sanful, 2009). It is also rich in vitamins A, B1, D2 and E; minerals: calcium, magnesium, sodium, potassium, copper and iron; and beneficial enzymes (Ayeh-Kumi *et al* 2014). Besides, it is rich in myristic acids, linoleic acid and oleic acid which are said to be cardiac preventive (Esteshola and Oraedu, 1996).

In order to alleviate the problem of malnutrition and food shortage, the development and use of these tubers is advocated (Bhat and Karim, 2009), and tigernut is one of the targeted crops for the alleviation of malnutrition in Ghana (Asare *et al* 2020). In Ghana, the available tigernut accessions have not been evaluated for nutritional composition to facilitate their proper use by breeding plant programmes. The objective of the study was to characterise Ghanaian tigernut accessions for proximate and mineral composition, as a guide for breeders for varietal development.

MATERIALS AND METHODS

Study area. The study was conducted at the Multipurpose Nursery of the College of Agriculture, University of Education, Winneba Mampong Ashanti in Ghana. Mampong-Ashanti is located on longitude 1.30 ºW and latitude 7.30º N, at an altitude of 395 m above sea level. The area has mean annual rainfall of 1270 mm, distributed in two seasons (March - July and September-November). Mean daily temperature is 27 ºC (Metrological Service, Mampong, 2010, www.statsgha.gov.gh).

Germplasm collection. Twenty-four accessions of tigernut were collected from six major tigernut growing regions in Ghana, namely Eastern region (Asukese Donkokrom, Nkwakwa), Volta region (Krachi), Upper East region (Bawku), Upper West region (Wa), Central region (Kasoa, Badwiase, Gomoa Feteh, Twifo Praso) and Bono East region (Techiman) (Table 1).

The accessions collected were kept in polyethylene bags and tagged with the names of towns where they were collected. The accessions were then named using the first letters of the towns where they were collected; and the colour of the nuts. Numbers were used to differentiate accessions from the same town, which had the same colour, for example WY1 meaning Wa Yellow, first accession.

Germplasm evaluation. The accessions were planted in a randomised block design (RCBD) with five replications, in plastic buckets. The volume of the buckets used was 1.22 litres each and was filled with sterilised sandy loam soil. Each bucket contained five stands of tigernut per genotype.

The stands were arranged 5 cm within rows and 5 cm between rows. The edible nuts were used for the study, and were raised under

TABLE 1. Source and colour of tigernut accessions collected from different part of Ghana for the study

Accessions	Collection place/area	Region	Colour
ADS	Asukese Donkorkrom	Eastern	Yellow
KB	Krachi	Volta	Black
KY	Krachi	Volta	Yellow
KAB	Kwanyako	Central	Black
KAY	Kwanyako	Central	Yellow
WY 1	Wa	Upper West	Yellow
DY	Bodwiase	Central	Yellow
BB	Bawku	Upper East	Black
BY	Bawku	Upper East	Yellow
TY	Techiman	Brong Ahafo	Yellow
BLB	Badwiase	Central	Black
BLY	Badwiase	Central	Yellow
CCB	Kasoa	Central	Black
CCY	Kasoa	Central	Yellow
AY	Nkwakwa	Eastern	Yellow
TPB	Twifo Praso	Central	Black
TPY	Twifo Praso	Central	Yellow
BKB	Badwiase	Central	Black
WY2	Wa	Upper West	Yellow
BKY	Badwiase	Central	Yellow
WB	Wa	Upper West	Black
GFB	Gomoa Fetteh	Central	Black
GFY	Gomoa Fetteh	Central	Yellow
ADL	Asukese donkokrom	Eastern	Yellow

ADS = Asukese Donkorkrom Short, KB = Krachi Black), KY = Krachi Yellow, KAB = Kwanyaako Asamoahkrom Black, KAY = Kwanyaako Asamoahkrom Yellow, WY1 = Waa Yellow 1, DY = Danso Yellow, BB = Bawku Black, BY = Bawku Yellow, TY = Techiman Yellow, BLB = Badwiase Local Black, BLY = Badwiase Local Yellow, CCB = Cape Coast Black, CCY = Cape Coast Yellow, AY = Aduamoah Yellow, TPB = Twifo Praso Black, TPY = Twifo Praso Yellow, WY2 = Waa Yellow 2, BKB = Bawjiase Kwahu Black, BKY = Bawjiase Kwahu Yellow, WB = Waa Black, GFB = Gommoa Fetteh Black, GFY = Gommoa Fetteh Yellow, ADL = Asukese Donkokrom Short

irrigation and manual weeding. One hundred grammes of nuts of each accession were washed with tap water to remove sand particles, before the nuts were air dried and put into transparent polythene bags before analysis.

Proximate analysis. The air-dried nut samples were analysed for moisture, ash and crude fibre in triplicates; using the Standard Protocols of Association of Official Chemist (AOAC, 1998). Nitrogen was determined by the micro-Kjedahl method, described by Pearson (1976); and converted into protein by multiplying with a factor of 6.25. Carbohydrate was determined by the difference method (Equation 1).

% Carbohydrates = 100 - % moisture - % protein - % fat - % ash .... Equation 1

The energy content was determined by Equation 2:

Energy = [(3.5X%CP) + (8.5X EE) + (3.5X NFE)]/10 ......………………...... Equation 2

Where:

CP = Crude Protein, EE = Ether Extract and NFE = Nitrogen Free Extract

Mineral analysis. The procedures described by AOAC (1998) were used for the mineral analysis. By these procedures, ash was digested with 3 ml of HCl and made up to the mark in a 100 ml standard flask with 0.36 HCl, before calcium, atomic absorption spectrometer (AAS). Phosphorus was determined by the spectrophotometric method and potassium by the flame photometer method.

Statistical analysis. The data collected were subjected to analysis of variance (ANOVA) using the GenStat statistical software, version 11.1 (GenStat, 2008). Dissimilarity matrix, based on Euclidean distance, was estimated using the same software. The scores of the dissimilarity matrix were used to perform a hierarchical cluster analysis (Ward, 1963). Principal Component Analysis (PCA) based on traits studied was performed to understand the relative contribution of the different traits to the total variation in tigernut. A biplot was drawn to demonstrate the relationship between the accessions and the traits, using the Eigen values associated with the components.

RESULTS

Proximate and mineral analysis. There were significant ($P<0.05$) difference among the 24 accessions of tigernut for proximate and mineral compositions (Table 2). Nitrogen Free Extracts (NFE) ranged from 3.84 to 37.33% for DY and BKB, respectively; while the energy content varied from 9.19% for accession WY to 25.05 for accession BLB. Overall, accession WY2 contained the highest amount of crude fiber (24.35%); while accession TPB contained the least amount (9.08%).

Ash content ranged from 1.33 to 11.30%, with accessions WY1 recording the highest and GFB the least amount (Table 2). Among the accessions studied, DY had the highest amount of crude protein; while accession BY had the least amount. Accession KAB recorded the highest amount of ether extract; while TPY recorded the least.

For moisture content, the range varied from 34.50% for BY to 49.50% for ADL. It was further observed that BKY had the highest amount of potassium (3.53 mg 100 g^{-1}), with ADS having the least (1.28 mg 100 g^{-1}). Phosphorus content ranged from 0.25 mg 100 g^{-1} for ADS to 1.19 mg 100 g^{-1} for CCY. Calcium also varied from 0.12 mg 100 g^{-1} in accession GFY to 0.40 mg100 g^{-1} in accession DY.

Cluster analysis. Proximate and mineral data were used to estimate Euclidean distances between the tigernut genotypes, and a dendrogram was constructed (Fig. 1). The analysis distinguished the 24 accessions into seven clusters, at 85% similarity index. Table 3 shows the means of proximate and mineral composition for the seven clusters; while Table 4 shows the clusters, number of accessions in each cluster and the traits that define each cluster based on the proximate and nutritional composition. Cluster I contained the highest number of accessions (10), which were characterised by high crude protein and crude fiber content. Cluster II consisted of 5 accessions characterised by high crude protein, crude fiber ash, moisture, calcium, potassium and phosphorus.

High crude fiber, ether extract, ash and energy characterised cluster III; which was also characterised by high moisture content, calcium, potassium and phosphorus. Clusters IV, VI and VII consisted of one accession

TABLE 2. Data for proximate and mineral composition of the tigernut accessions evaluated In Ghana

Accessions	K mg 100 g^{-1}	P mg 100 g^{-1}	% C F	% ASH	Ca mg 100 g^{-1}	%CP	%FAT	%Moisture	%Energy	%NFE
ADS	1.28±0.01	0.24±0.03	17.63±0.06	3.33±0.33	0.20±0.06	5.56±0.08	9.67±0.33	40.17±0.16	18.44±0.31	23.63±0.14
KB	2.27±0.03	0.59±0.06	15.79±0.08	3.50±0.50	0.31±0.06	4.80±0.05	9.33±0.16	43.33±0.16	17.75±0.16	23.25±0.77
KY	2.16±0.01	0.54±0.01	20.22±0.05	6.33±0.33	0.20±0.06	4.83±0.06	11.83±0.16	45.33±0.16	15.76±0.14	11.45±0.05
KAB	1.89±0.06	0.35±0.06	12.97±0.07	2.16±0.16	0.20±0.01	4.86±0.03	19.33±0.66	41.17±0.16	24.96±0.37	19.50±0.56
KAY	2.20±0.03	0.41±0.06	10.72±0.06	2.33±0.33	0.20±0.06	5.53±0.06	15.17±0.16	42.33±0.16	23.20±0.18	23.92±0.49
WY	3.38±0.06	0.85±0.03	11.63±0.02	11.33±0.33	0.35±0.06	5.03±0.03	8.33±0.16	54.17±0.16	12.17±0.14	9.50±0.61
DY	3.19±0.01	0.83±0.03	20.42±0.02	6.16±0.16	0.40±0.06	5.73±0.03	15.50±0.28	48.33±0.33	16.53±0.22	3.84±0.59
BB	2.01±0.08	0.44±0.06	15.92±0.04	6.50±0.28	0.26±0.03	5.06±0.06	15.50±0.28	37.17±0.16	21.90±0.09	19.85±0.49
BY	2.15±0.06	0.45±0.01	18.00±0.04	5.16±0.16	0.23±0.06	4.16±0.03	13.17±0.16	34.50±0.28	21.40±0.18	25.00±0.41
BY	2.15±0.06	0.45±0.01	18.00±0.04	5.16±0.16	0.23±0.06	4.16±0.03	13.17±0.16	34.50±0.28	21.40±0.18	25.00±0.41
TY	3.52±0.01	0.96±0.06	13.28±0.02	5.83±0.44	0.20±0.01	4.36±0.03	6.33±0.16	50.50±0.28	13.80±0.29	19.69±0.60
BLB	2.22±0.03	0.42±0.06	15.49±0.02	3.16±0.16	0.16±0.06	4.73±0.06	19.17±0.16	37.17±0.16	25.05±0.18	20.28±0.24
BLY	2.68±0.06	0.76±0.01	14.30±0.05	6.16±0.16	0.19±0.06	5.16±0.03	9.00±0.28	38.33±0.33	18.92±0.22	27.03±0.55
CCB	2.90±0.01	0.82±0.03	14.84±0.02	4.83±0.44	0.12±0.06	5.26±0.03	18.17±0.16	38.50±0.28	23.72±0.28	18.40±0.48
CCY	3.42±0.23	1.19±0.06	18.18±0.01	1.50±0.28	0.12±0.01	5.56±0.03	11.33±0.16	42.17±0.16	19.02±0.13	21.25±0.02
AY	3.02±0.03	0.84±0.01	10.57±0.03	2.50±0.28	0.34±0.03	4.83±0.06	5.17±0.16	52.17±0.16	14.75±0.20	24.76±0.15
TPB	3.40±0.03	1.07±0.06	9.09±0.01	8.50±0.28	0.23±0.06	4.56±0.03	9.33±0.16	38.50±0.28	20.04±0.13	30.01±0.33
TPY	3.81±0.01	1.08±0.01	13.68±0.02	2.33±0.33	0.16±0.06	5.26±0.03	3.17±0.16	44.33±0.16	15.46±0.08	31.22±0.57
WY2	3.29±0.03	0.75±0.06	24.35±0.07	6.16±0.16	0.12±0.01	5.13±0.08	4.33±0.33	49.50±0.28	9.16±0.30	10.51±0.27
BKB	2.75±0.06	0.53±0.06	11.97±0.02	1.16±0.16	0.35±0.06	5.20±0.05	7.50±0.28	36.83±0.44	21.26±0.06	37.33±0.84
BKY	3.52±0.06	0.89±0.03	9.37±0.07	2.83±0.44	0.20±0.06	5.06±0.06	5.17±0.16	44.50±0.28	17.74±0.31	33.06±0.53
WB	3.00±0.03	0.51±0.01	12.35±0.01	2.16±0.16	0.18±0.06	4.86±0.03	13.33±0.16	39.67±0.44	22.70±0.18	27.61±0.39
GFB	3.45±0.03	0.75±0.03	11.70±0.05	1.33±0.16	0.20±0.06	4.83±0.06	11.50±0.28	35.50±0.28	23.76±0.12	35.13±0.63
GFY	3.14±0.03	0.56±0.03	12.50±0.08	1.33±0.33	0.12±0.01	5.53±0.03	3.33±0.33	46.33±0.16	15.61±0.05	30.97±0.78
ADL	3.15±0.06	0.57±0.01	10.89±0.01	2.50±0.28	0.16±0.06	4.86±0.0	5.00±0.28	46.50±0.28	16.54±0.08	30.25±0.75
LSD (5%)	0.15	0.02	0.060	0.62	0.02	0.14	0.75	0.69	0.49	1.24
CV (%)	3.10	1.30	0.30	9.20	5.40	1.70	4.40	1.0	1.60	3.30

ADS = Asukese Donkorkrom Short, KB = Krachi Black), KY = Krachi Yellow, KAB = Kwanyaako Asamoahkrom Black, KAY = Kwanyaako Asamoahkrom Yellow, WY = Waa Yellow, DY = Danso Yellow, BB = Bawku Black, BY = Bawku Yellow, TY = Techiman Yellow, BLB = Badwiase Local Black, BLY = Badwiase Local Yellow, CCB = Cape Coast Black, CCY = Cape Coast Yellow, AY = Aduamoah Yellow, TPB = Twifo Praso Black, TPY = Twifo Praso Yellow, WY2 = Waa Yellow 2, BKB = Bawjiase Kwahu Black, BKY = Bawjiase Kwahu Yellow, WB = Waa Black, GFB = Gommoa Fetteh Black, GFY = Gommoa Fetteh Yellow, ADL = Asukese Donkokrom Short

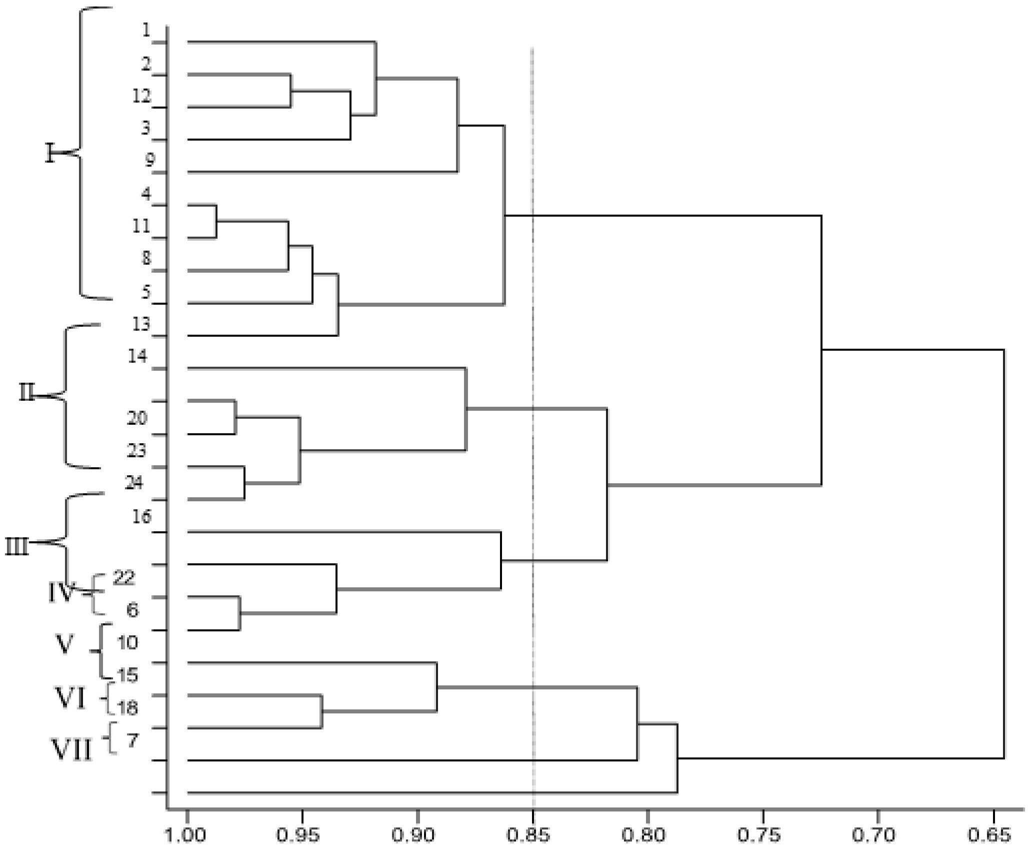

Figure 1. Dendrogram showing the diversity in proximate and mineral composition among the twenty-four Ghanaian tigernut accessions used in the study.

each, WY1, BKB and DY, respectively. Cluster 4 was characterised by high ether extract, ash, NFE and energy content; while clusters VI and VII were characterised by high NFE, energy, phosphorus and potassium.

Principal component analysis. Variations among the accessions for the proximate and mineral contents were also assessed using Principal Components Analysis (PCA). The first five principal components (PC) extracted gave an accumulation of over 90% of the total variation noted among the tigernut accessions, for the proximate and mineral composition (Tables 5 and 6). Of these, up to 33.4 % of the total variation was explained by PC1 alone, with Eigen value of 3.33. Moisture, energy, phosphorus and potassium contents had positive and high weightings for the PC1 axis. PC2 with Eigen value of 2.39 explained up to 24% of the total variation, with ether extract, crude fiber, and ash having high and positive weightings. PC3, PC4 and PC5 explained 13.4, 10.4 and 9.1%, respectively, of the total variation with the Eigen values 1.33, 1.04 and 0.91, respectively. The distribution of the accessions in all quarters of the biplot showed the wide diversity among the accessions for the proximate and mineral components (Fig. 2).

TABLE 3. Proximate and mineral composition for the seven clusters of twenty-four tigernut accessions in Ghana

Variable	Clusters							
	I	II	III	IV	V	VI	VII	Grand
%CP	5.311	5.183	4.8200	5.0334	4.6000	5.1834	5.0167	5.0361
%C F	17.200	19.156	15.441	11.614	11.926	11.609	11.833	14.410
%Fat	10.111	9.999	17.066	11.708	5.7500	4.1668	9.5000	10.402
%Ash	2.777	7.500	4.3668	4.7918	4.1665	2.2498	1.2500	4.1319
%Moisture	41.889	49.333	37.700	39.708	51.333	45.416	36.166	42.791
%NFE	22.711	8.826	20.605	27.144	22.223	31.374	36.233	23.227
%Energy	18.402	13.403	23.405	21.214	14.275	16.337	22.512	18.734
Ca(mg 100 g^{-1})	0.213	0.271	0.198	0.205	0.273	0.165	0.280	0.221
P(mg 100 g^{-1})	0.677	0.745	0.500	0.689	0.905	0.778	0.645	0.686
K(mg 100 g^{-1})	2.328	3.006	2.238	2.826	3.273	3.406	3.105	2.828

CP = Crude Protein, CF = Crude Fibre, NFE = Nitrogen Free Extract, Ca = Calcium, P = Phosphorus, K = Potassium

TABLE 4. Tigernut clusters based on proximate and nutritional composition in Ghana

Cluster	Number of accessions	Accessions	Traits
1	10	ADS, KB, BLY, KY, BY, KAB, BLB, BB, KAY, CCB	High crude protein and crude fiber content
2	5	CCY, TPY, BKY, GFY, ADL	High crude protein, crude fiber ash, moisture, calcium, potassium and phosphorus
3	4	TPB, WY2, WB, GFB	High crude fiber, ether extract, ash and energy
4	1	WY1	High ether extract, ash, NFE and energy content
5	2	TY, AY	High moisture content, calcium, potassium and phosphorus
6	1	BKB	High NFE, energy, phosphorus and potassium
7	1	DY	High NFE, energy, phosphorus and potassium

TABLE 5. Principal Component Analysis for the proximate and mineral composition of the twenty-four tigernut accessions t in Ghana

Principal components	Eigen value	Proportion	Cumulative
1	3.3395	0.334	0.334
2	2.3960	0.240	0.574
3	1.3356	0.134	0.707
4	1.0415	0.104	0.811
5	0.9148	0.091	0.903
6	0.4696	0.047	0.950
7	0.3906	0.039	0.989
8	0.1124	0.011	1.000
9	0.0000	0.000	1.000
10	0.0000	0.000	1.000

TABLE 6. The first five Principal Components of the proximate and mineral composition of the accessions studied

Variables	PC1	PC2	PC3	PC4	PC5
%Crude protein	0.046	0.064	-0.617	-0.284	0.592
%fat	-0.384	0.309	0.111	0.275	0.379
%Crude fiber	0.043	0.464	-0.397	0.230	-0.215
%Ash	0.230	0.367	0.432	0.238	-0.012
%Moisture	0.460	0.121	-0.041	-0.283	-0.029
%NFE	-0.164	-0.587	0.038	-0.143	-0.130
%Energy	-0.500	-0.099	0.118	0.167	0.309
Ca (mg 100 g^{-1})	0.084	0.184	0.492	-0.559	0.373
P (mg 100 g^{-1})	0.384	-0.206	0.053	0.445	0.370
K (mg 100 g^{-1})	0.390	-0.324	0.028	0.309	0.264
Eigen value	3.3395	2.3960	1.3356	1.0415	0.9148
Proportion (%)	33.4	24.0	13.4	10.4	9.1
Cumulative (%)	33.4	57.4	70.7	81.1	90.3

DISCUSSION

Proximate and mineral analysis. The significant variations among the accessions for proximate and mineral composition is an indication of the presence of a high degree of genetic variation. This implies presence of great potential of the accessions for utilisation in future breeding programmes for varietal development of nutritious tigernut in Ghana; and also for recommendation to be included in the diets of Ghanaians. The high content of the proximate and mineral content of most of the accessions studied, provides an assurance that tigernut can solve the malnutrition problems in the world, hence more research need to be done. Several authors (Ayasan *et al.*, 2020; Madaki *et al.*, 2018; Emurotu, 2017; Bado *et al.*, 2015) reported significant nutritional content in tigernut.

Cluster analysis. Cluster analysis based on the proximate and mineral composition of tigernut assigned the genotypes into seven

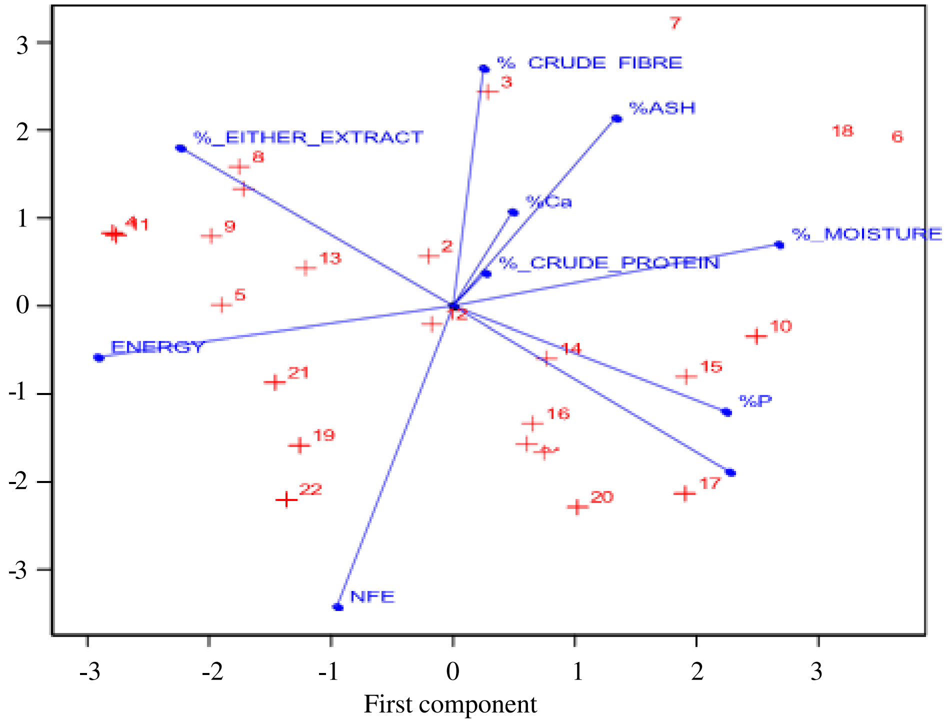

Figure 2. Biplot of the proximate and mineral composition of the twenty-four Ghanaian tigernut accessions used in the study.

different groups (Fig. 1). The groupings of the accessions from the same origin and colour into different clusters, suggests diversity among accessions within a geographical origin and among accessions beyond geographical origin. Selection and crossing of genotypes from different clusters would help in bringing together favourable genes for quality traits so as to breed highly nutritional varieties of tigernut. Selection of accessions from the same cluster for hybridisation will, therefore, not yield favourable results. Blessing *et al.* (2011) reported on similar results in *cucurbita* spp.

Principal component analysis. The fact that moisture, phosphorus, potassium and ash content were the distinguishing characters among tigernut genotypic clusters (Fig. 2), implies that focus should be put on these traits for the development of nutritious tigernut varieties in Ghana. All the above nutrients had positive eigen values, indicating that their maximum to the discrimination among the accessions. These nutrients could, therefore, be considered during nutritional improvement of tigernut through selection. Principal component analysis (PCA) helps to identify traits that have substantive and meaningful contribution towards the observed variation (Prasad *et al.*, 2010).

CONCLUSION

The study has revealed significant diversity among the tigernut accessions for proximate and mineral composition, giving room for the selection of superior accessions to be included in varietal development programmes in Ghana. Several accessions (BKB, BLB, BKY, WY1, WY2, DY and KAB) recorded high proximate and mineral content and can, therefore, be considered in national and institutional breeding programmes for varietal development.

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