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Research Article
Nutritional Properties Assessment of Endogenous and Improved Varieties of Maize (*Zea mays* L.) Grown in Southern Benin

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Absract

Background and Objectives: A wide range of maize varieties is used in Benin but information on the nutritional characteristics of these varieties are not well known. This study aims to assess the nutritional composition of maize varieties in use in the southern region of Benin with the purpose of providing consumers accurate information for better choice. **Materials and Methods:** Moisture, ash, protein, fiber and fat contents were determined according to Association of Official Analytical Chemists and American Association of Cereal Chemists methods. Sugar and organic acids were assessed using High Performance Liquid Chromatography methods and amino acids profile was established according to Rosen method using glutamic acid. **Results:** The maize varieties were classified into 5 clusters according to their macro nutrients composition and 4 clusters based on their sugar and organic acids contents. Varieties of group 5 were very rich in protein (14.34 g/100 g), while the highest fat content (7.22 g/100 g) was observed for group 2 varieties. The highest carbohydrate contents obtained were 80.64 g/100 g, 80.11 g/100 g and 79.15 g/100 g for groups 1, 4 and 5 varieties respectively. Moreover the dendrogram gave four homogeneous clusters according to sugars and organic acids composition. Varieties of groups 2, 3 and 4 had almost the same fructose contents ranging between 0.04 and 0.06%; varieties of group 1 contained the highest contents of raffinose, sucrose and glucose; those of group 2 were very rich in propionate and fructose. **Conclusion:** It is concluded that some of maize varieties investigated contained high level of protein. Furthermore glutamic acid was the predominant amino acid while the least amino acid was methionine. Those varieties, owing to their protein and amino acids contents could have many benefits by providing vital constituents to the body.

Keywords: Maize, varieties, composition, macro nutrients, sugar, amino acids, Benin

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Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Maize (*Zea mays* L.) is the first cereal crop produced in the world[1,2]. It is an important food resource in tropical and subtropical regions. Indeed, maize is a staple food for many African countries[3]. In West Africa, maize cropping is now classified as a main agricultural sector and therefore, has been benefiting an important political support. Its added value estimated over 2 billion Euros, which benefits mainly rural people provides more than 10 million of permanent jobs[4]. Moreover, maize is recognized as the most energetic cereal due to its nutritional values (starch, protein, fat and minerals) and economic (single crop to grow, harvest and store)[5,6]. Moreover, maize plays a significant role in the national and regional trade transactions[7]. Besides, maize is one of the 13 sectors selected to be promoted by the Ministry of Agriculture, Livestock and Fisheries (MAEP) of Benin in its Strategic Plan for Agricultural Sector Revival (PSRSA) to ensure food security and economic growth of Benin[8].

Amongst all food crops in Benin, maize is conspicuous by the large extension of its cultivation area due to its easiest adaptation and its high consumption[9]. It is the main food crop grown in Benin. In fact, the national production of maize was estimated at 1,345,820.9 tons in 2013[10]; its area of cultivation was about 70% of the total area devoted to cereals in Benin and represents about 75% of cereal production[8]. Maize is the staple food of population in Southern Benin. The modes of consumption differ according to regions and social categories (fresh or green product, husked grains dried and cooked, dry grains ground into flour or semolina)[11]. In agribusiness, maize is used to make beverages (mostly beer), infant food and as animal feed (feed grain and by-products such as bran, cakes and germs)[11]. Maize producers have a wide range of maize varieties they grow and of which some are often oriented to specific agro-food processing because of their technological characteristics. Although the agronomic performances of most of these varieties are well known, their nutritional aptitude is not well documented. Thus, the study was aimed to characterize the maize varieties in order to point out suitable information to guide their choice according to user's needs.

MATERIAL AND METHODS

Material: The plant material consists of 7 grain samples of improved varieties of maize and 23 grain samples of indigenous varieties of maize listed in Table 1. These samples were collected in Southern Benin, precisely in 24 villages; all located in the agro-ecological zones V, VI, VII and VIII[12]. The collected samples were stored in a cold room (4°C) of South Agricultural Research Centre (CRA-Sud) of Niaouli, Benin.

Methods

Proximate analyses and calorie contents determination: Moisture, ash, protein, fiber and fat contents of maize samples were determined according to AOAC[13] and AACC[14] methods respectively. The calorie content was determined using a bomb calorimeter (Parr Instrument Company, Moline, Illinois 61265 USA). Carbohydrate content other than fibers was calculated by the difference between total dry matter and other nutrients of this dry matter such as proteins, ash, fats and fibers.

Determination of organic acids and sugars: Sugars and organic acids were determined using an HPLC with ion exclusion column (Aminex HPX-87H) thermo-stated at 37°C following the method of Mestres and Rouau[15]. Standard solutions of sugars (glucose, fructose, raffinose and sucrose) and organic acids (citrate and malate) were used for calibration. The elution was carried out with 5 mM sulfuric acid at a flow rate of 0.6 mL min^{-1}. For the extraction, 25 mg of flour of a chosen maize sample were suspended in 1 mL of sulfuric acid solution (5 mM). The mixture was stirred for 1 h at room temperature (25±2°C) and then centrifuged at 10000 rpm for 5 min. The resulting supernatant was filtered with a syringe of 0.45 µm and 20 µL; the filtrates were injected into the HPLC system (Spectrasystem UV 2000, Knauer RI Detector 2300, Pump 1000). Soluble sugars were quantified by refractometry method and organic acids were detected by UV spectrophotometry at 210 nm. The various compounds were identified by their retention times and quantified using peak areas (compared to standard). Results were expressed in g/100 g of product.

Determination of amino acids profile: Amino-acids composition of samples was determined according to Rosen[16] using glutamic acid as reference. One gram of maize flour was suspended in 100 mL distilled water in a hydrolysis tube. The suspension was shook at 4°C for 2 h and centrifuged at 3000 rpm for 15 min. Then 100 µL of hydrolysate obtained were taken in a tube and 900 µL distilled water, 500 µL KCN 2% in acetate buffer and 500 µL ninhydrine 3% solution added. The mixture was tightly closed and shook using a vortex. After an incubation period of 15 min at 100°C, the reaction was stopped by adding 5 mL isopropanol-water (1/1: v/v). The products of the reaction were detected at 570 nm using a spectrophotometer 840-209900 (Biomate 3S UV-Visible).

Table 1: Endogenous and improved maize varieties collected in different areas of the study

Sample codes	Local name of varieties	Types	Sampling zones	Agro-ecological zones
TF2013-2-009	Tchoké	Local	Dohinhonko	VI
AB-3-2013-017	Tchigbadé	Local	Adjaïgbonou	VII
AB-3-2013-051	Acthivi or ghanaBaffokouin	Local	Gbenounkochihoué	VI
AB-3-2013-018	Edouanti	Local	Adjaïgbonou	VII
AB-3-2013-044	Kpégladé	Local	Ahogbéya	VI
TF2013-2-016	Gnonli	Local	Hounsa/Niaouli	VI
TF2013-2-004	Massahoué	Local	Anavié-Sèdjè	VI
AB-3-2013-053	Kpédévi-non-ovo	Local	Gbénounkochihoué	VI
TF2013-2-014	Houéglékoun	Local	Houéglé	VII
TF2013-1-021	Massahoué	Local	Sémè	VI
TF2013-2-015	Gogodomé	Local	Hounsa/Niaouli	VI
TF2013-2-010	Edouatin	Local	Dohinhonko/Sèkanmey	VI
AB-3-2013-001	DMR-ESW	Improved	Covè	VI
TF2013-2-003	Ovinonboè	Local	Anavié/Houèzeto	VI
AB-3-2013-035	Carder	Improved	Sènouhouè	VI
TF2013-1-018	Tchahounkpo	Local	Vidjinan	VI
AB-3-2013-040	Carder/wilin-wilin	Improved	Ahogbéya	VI
TF2013-1-035	Akobi-gbadé	Local	Kpankou	V
AB-3-2013-021	Tchankpo	Improved	Adjaïgbonou	VII
AB-3-2013-004	White	Improved	Avlimè	VI
AB-3-2013-048	Edouatchi	Local	Sèglahoué	VI
AB-3-2013-011	Sounwèkoun	Local	Lohounvodo	VIII
TF2013-1-020	EVDT97STR	Improved	Ayihounzo	VI
TF2013-2-011	Tchikoun	Local	Agonmey	VII
AB-3-2013-009	Houévi	Local	Gbèdji	VI
TF2013-1-019	Massahoué	Local	Vidjinan	VI
TF2013-2-002	Yagbo	Local	Anavié/Sèdjè	VI
AB-3-2013-043	Gotin-wlin	Local	Ahogbéya	VI
AB-3-2013-014	Sounaton-kouin	Local	Djèhadji	VIII
AB-3-2013-039	Carder	Improved	Agohoué	VI

Statistical analysis of data: A numerical classification was performed with SAS software version 9.2 and the coefficient $R^2 = 0.50$ was determined on the basis of various parameters analyzed in order to subdivide all varieties in a restricted number of groups consisting of fairly homogeneous elements. The groups of maize varieties then obtained were subjected to analysis of variance using SAS software version 9.2. The test of Student Newman Keuls (SNK) was used for the separation of means at 5% threshold[17]. Then the principal components analysis (PCA) was carried out to establish the relationship between groups of maize varieties and determined parameters.

RESULTS

Macro nutrients composition of maize varieties collected in south Benin: The macro nutrients composition of 30 maize varieties studied allowed their distribution in 5 groups more or less homogeneous represented by a dendrogram (Fig. 1). The largest group (group 1) consisted of 18 varieties; this was followed by group 2 comprising 8 varieties, group 3 with 2 varieties and groups 4 and 5 with 1 variety each. The quantitative description of measured variables associated with different groups of maize varieties is showed in Table 2.

The analysis of variance revealed that the 5 groups of maize varieties were very significantly ($p<0.001$) different in terms of their protein, carbohydrates, ash and calorie contents; significantly ($p<0.05$) different in relation to their fat content but were similar ($p>0.05$) relatively to the fiber composition (Table 2). Results of SNK test showed that maize varieties in group 1 were rich in fats and carbohydrates, those in group 2 were very rich in fats, the varieties in group 3 were very rich in ash and low in fats. The variety in group 4 was very rich in fiber and carbohydrates with high level in calorie and the variety in group 5 was very rich in protein.

The results of principal component analysis on its various maize groups and the analyzed parameters were used to describe the relationship between them and refine their analysis. These results indicated that the first two axes explained 73.10% of the total information (Table 3).

Correlation between the chemical characteristics and axes is showed in Table 4. The first principal component

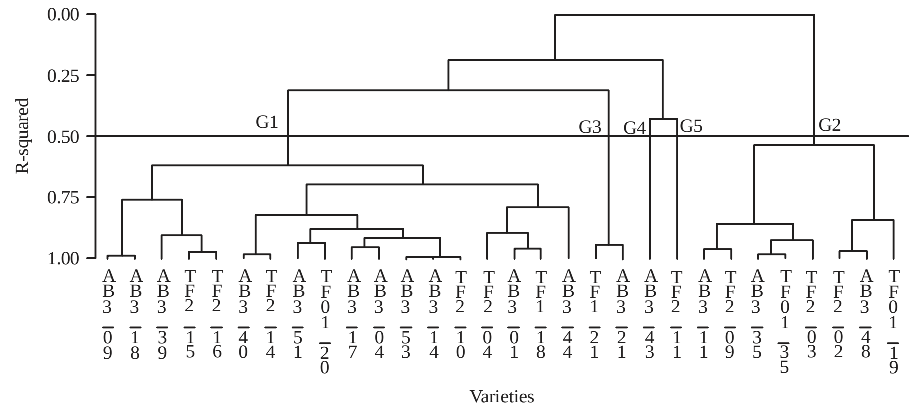

Fig. 1: Dendrogram showing different groups of maize varieties

Table 2: Quantitative description (Means±Standard Deviation) of measured variables associated with different groups of maize varieties

	Clusters						
Variables	1	2	3	4	5	F	CV
Moisture (%)	12.48±0.09^{cx}	12.19±0.12^{c}	12.29±0.11^{c}	13.20^{b}	14.69^{a}	24.44***	1.6420
Energy(kcal/100 g) dm	451.65±3.73^{b}	461.78±5.27^{b}	461.30±7.85^{b}	558.12^{a}	457.26^{b}	24.00***	1.7582
Fats (g/100 g) dm	5.98±0.37^{a}	7.22±0.64^{a}	4.92±0.01^{ab}	5.64^{ab}	3.23^{b}	3.16*	9.8580
Proteins (g/100 g) dm	10.30±0.22^{c}	12.48±0.34^{b}	10.81±0.39^{c}	9.50^{c}	14.34^{a}	106.98***	4.3260
ash (g/100 g) dm	1.55±0.07^{b}	1.50±0.07^{b}	3.18±0.12^{a}	1.22^{b}	1.50^{b}	22.49***	7.2800
Fibers (g/100 g) dm	1.96±0.16^{bc}	2.31±0.35^{abc}	2.52±0.47^{ab}	3.23^{a}	1.10^{c}	2.80ns	20.1040
Carbohydrates (g/100 g)	80.64±0.39^{a}	76.47±0.52^{b}	78.71±0.94^{ab}	80.11^{a}	79.15^{a}	9.80***	1.0800

[x]Mean±Standard Deviation, [a,b,c]Means followed by the same alphabetical letter on the same row are not significantly different (p>0.05) after the test of StudentNewman-Keuls, *Significant at 0.05, **Higly significant at 0.01, ***Very highly significant at 0.001, dm: Dry matter

Table 3: Eigen value of the first three principal components

Axis of PC1	Eigen value	Proportion	Cumulative proportion
PC1	3.1356	0.448	0.448
PC2	1.9818	0.283	0.731
PC3	1.2101	0.173	0.904

Table 4: Correlation between principal components and variables

Variables	Axe 1	Axe 2
Moisture	-0.428*	-0.430*
Energy	0.316*	-0.496*
Fats	0.419*	0.313*
Proteins	-0.506*	0.191ns
Ash	0.029ns	0.346*
Fibers	0.532*	-0.101ns
Carbohydrates	0.037ns	-0.549*

*p<0.05, ns: Non significant

opposes the calorie, fat and fiber contents to water and protein contents. Thus, any maize variety with high calorie, fat and fiber contents had a low water and protein contents and vice versa.

The projection of the variables on the axes defined by the groups of varieties (Fig. 2) show that the variety in group 5 had the highest protein content and the lowest fiber content while those in groups 2 and 3 were rich in fats and ashes, respectively. The varieties in group 4 were rich in carbohydrates, fiber and calorie and those in group 1 were very rich in carbohydrates.

Sugar and organic acids composition of maize varieties collected in southern Benin: The sugar and organic acids composition of the 30 maize varieties studied allowed their classification into four clusters (Fig. 3). The largest cluster (group 2) consisted of 21 varieties while the small one is represented by cluster 4 with only one variety. The average amounts of various sugar and organic acids determined in maize varieties per cluster are summarized in Table 5.

The analysis of variance performed on the different groups obtained revealed that they were very highly significantly different (p<0.001) when considering their contents in the six parameters (raffinose, sucrose, oxalate, malate, citrate and acetate), highly significantly different (p<0.01) when considering their contents in two parameters (glucose and fructose) but not significantly different (p>0.05) when considering the propionate, lactate and formate contents (Table 5). The test of SNK indicated that varieties in group 1 were richer in raffinose, sucrose and glucose and did not contain at all fructose and organic acids. The maize varieties in the group 2 contain high levels of propionate and were rich in fructose; these same varieties were very poor in lactate and formate. Varieties in group 3 were rich in malate and citrate. Those in group 4 were rich in oxalate and acetate.

Table 5: Quantitative description (Means±Standard Deviation) of measured variables associated with different groups of maize varieties

	Clusters					
Variables (% dm)	1	2	3	4	F	CV
Raffinose	0.35±0.01[ax]	0.02±0.00[b]	0.03±0.02[b]	0.02±0.00[b]	333.24***	46.99
Fructose	0.00±0.00[b]	0.04±0.01[a]	0.04±0.00[a]	0.06±0.00[a]	5.63**	22.71
Sucrose	1.31±0.06[a]	0.07±0.01[b]	0.09±0.04[b]	0.04±0.00[b]	332.21***	46.84
Glucose	0.17±0.01[a]	0.07±0.01[b]	0.08±0.02[b]	0.10±0.00[ab]	5.45**	35.21
Oxalate	0.00±0.00[b]	0.15±0.03[b]	0.17±0.06[b]	0.61±0.00[a]	10.31***	41.71
Propionate	0.00±0.00[a]	0.21±0.09[a]	0.12±0.07[a]	0.00±0.00[a]	0.56ns	75.47
Malate	0.00±0.00[b]	0.00±0.00[b]	0.03±0.01[a]	0.01±0.00[b]	9.69***	68.75
Citrate	0.00±0.00[b]	0.00±0.00[b]	0.04±0.01[a]	0.00±0.00[b]	47.25***	92.48
Acetate	0.00±0.00[b]	0.03±0.01[b]	0.01±0.01[b]	5.33±0.00[a]	7399.26***	96.89
Lactate	0.00±0.00[a]	0.00±0.00[a]	0.00±0.00[a]	0.00±0.00[a]	0.53ns	59.98
Formate	0.00±0.00[a]	0.00±0.00[a]	0.00±0.00[a]	0.00±0.00[a]	0.63ns	54.91

[x]Mean±Standard Deviation, Means followed by the same alphabetical letter on the same row are not significantly different (p>0.05) after the test of Student Newman-Keuls, ns: Non-significant, *Significant at 0.05, **Highly significant at 0.01. ***Very highly significant of 0.001, dm: Dry matter

Table 6: Eigen value of the first three principal components

Axis du PC1	Eigen value	Proportion	Cumulative proportion
PC1	5.1840	0.471	0.471
PC2	3.4586	0.314	0.786
PC3	2.3574	0.214	1.000

Table 7: Correlation between variables and principal components

Variables	Axe 1	Axe 2
Raffinose	0.437*	0.048 ns
Fructose	-0.396*	-0.216 ns
Sucrose	0.437*	0.057 ns
Glucose	0.429*	-0.113 ns
Oxalate	-0.230 ns	-0.386*
Propionate	-0.268 ns	0.415*
Malate	-0.231 ns	-0.177 ns
Citrate	-0.148 ns	-0.067 ns
Acetate	0.118 ns	-0.418*
Lactate	-0.179 ns	0.449*
Formate	-0.179 ns	0.449*

*p<0.05, ns: Non-significant

The results of principal component analysis on different groups of maize and variables indicated that the first two axes account for 78.6% of the total variations observed and of which 47.1% are represented by axis 1 and 31.4 % by axis 2 (Table 6).

Correlation between the chemical characteristics and axes is presented in Table 7. The first principal component opposes the raffinose, sucrose, glucose contents to that of fructose. It appears that any variety of maize having high raffinose, sucrose and glucose contents contained low level of fructose and vice-versa.

The projection of the variables on the axes defined by the groups of varieties (Fig. 4) revealed that the varieties in group 1 had high levels of sucrose, glucose and raffinose, while those in group 2 showed high levels of propionate and fructose and were poor in formate and lactate. As for varieties in group 3, they were very rich in citrate and malate and those in group 4 were rich in oxalate and acetate.

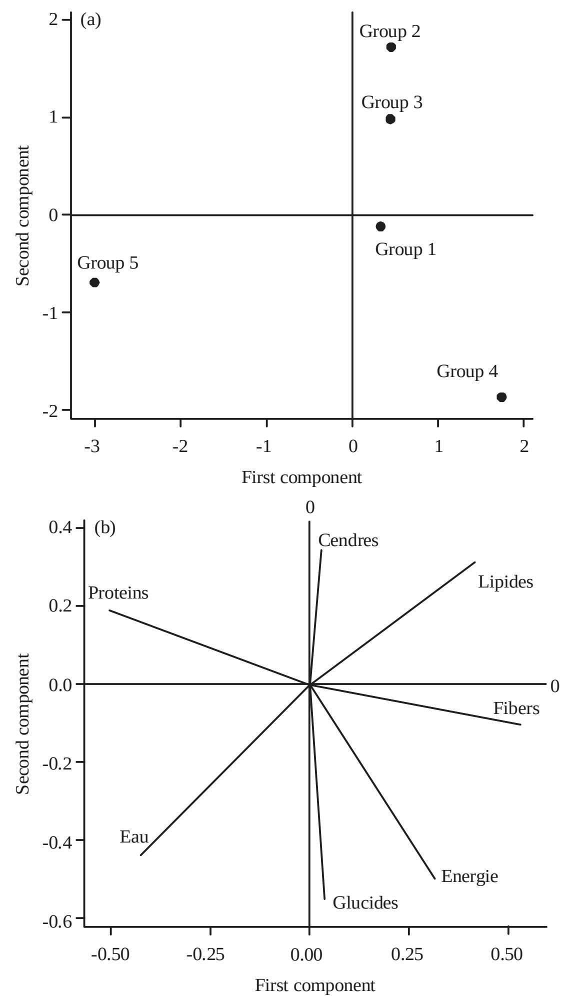

Fig. 2: Relationship between maize groups and parameters measured from a Principal Component Analysis (PCA)

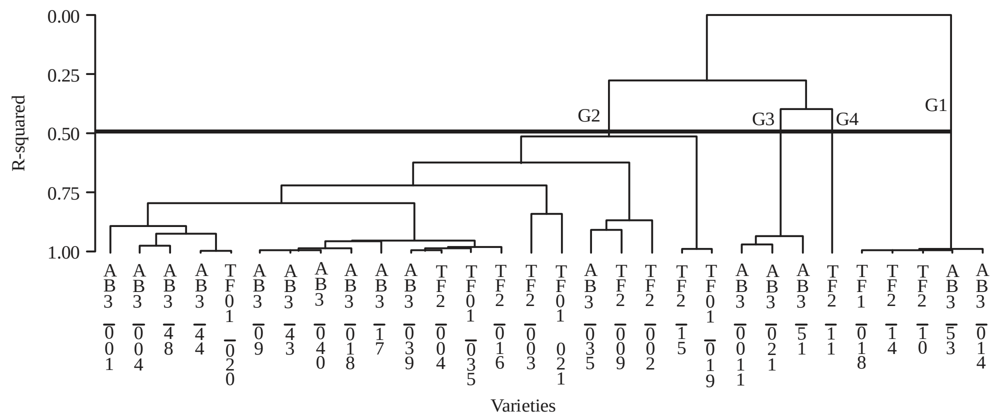

Fig. 3: Dendrogram showing different groups of maize varieties

Table 8: Descriptive statistics of quantitative variables measured on the varieties

Variables (mg/100 g CP)	Min	Max	Mean	Er sta
Acide glutamique	1.4	1.7	1.504	1.130
Proline	0.6	0.8	0.680	0.760
Leucine	0.9	1.2	1.048	0.770
Acide Aspartique	0.6	1.2	0.920	1.950
Alanine	0.6	0.8	0.720	0.640
Phénylalanine	0.4	0.6	0.468	0.620
Arginine	0.3	0.4	0.320	0.400
Thréonine	0.2	0.6	0.352	0.820
Valine	0.3	0.5	0.376	0.522
Histidine	0.2	0.3	0.232	0.476
Serine	0.3	0.5	0.380	0.570
Méthionine	0.0	0.2	0.112	0.430
Cystéine	0.2	0.2	0.200	0.000
Tryptophane	0.6	1.0	0.804	0.970
Isoleucine	0.3	0.4	0.312	0.330
Glycine	0.2	0.3	0.256	0.500
Tyrosine	0.2	0.4	0.272	0.610
Lysine	0.1	0.6	0.336	1.350

CP: Crude protein, values are means of triplicate determination

Amino acids profile of maize varieties: The results of the descriptive analysis on amino acids data are presented in Table 8. A total of 18 amino acids were detected in the varieties of maize samples. There are consisted of nine essential amino acids (lysine, valine, methionine, phenylalanine, histidine, tryptophane, leucine, isoleucine and threonine) and nine non-essential ones (alanine, aspartic acid, glutamic acid, proline, arginine, serine, cysteine, glycine and tyrosine) (Table 9). Among these, glutamic acid was the predominant amino acid detected while methionine was the least one.

DISCUSSION

The study has permitted to determine the macro nutrients, simple sugars and organic acids composition of 30 maize varieties collected in southern Benin, then to classify these maize varieties into different groups consisting of relatively homogeneous elements according to their composition. Among the groups obtained in terms of macro nutrients, variety of group 4 was very rich in fiber, carbohydrates and calorie, group 5 was very rich in protein and carbohydrates, as for varieties of group 3, they contained the highest contents of ash. Varieties of group 1 showed high amounts in fat and carbohydrates, while those of group 2 were very rich in fats (Table 2). The determination of moisture content of maize samples aimed to assess the quality of drying and to predict the shelf life of maize varieties. The average values of moisture contents of varieties investigated ranged between 12 and 14.7%. Thirty percent of the analyzed samples showed moisture contents higher than the levels of about 12-13% recommended for a good storage[18]. Indeed, a

Table 9: Amino acids profile of maize samples

N°Echantillon (mg/100 g)	Glu_Gln	Pro	Leu	Asp_Asn	Ala	Phe	Arg	Thr	Val	His	Ser	Met	Cys	Try	Ile	Gly	Tyr	Lys
AB-3-2013-9	1.61	0.72	1.11	0.95	0.82	0.53	0.36	0.31	0.48	0.29	0.45	0.14	0.28	0.86	0.36	0.32	0.21	0.18
AB-3-2013-11	1.53	0.68	1.08	1.21	0.78	0.60	0.41	0.42	0.50	0.24	0.36	0.11	0.24	0.70	0.34	0.32	0.22	0.23
AB-3-2013-43	1.42	0.82	1.22	1.11	0.72	0.47	0.38	0.47	0.43	0.31	0.42	0.21	0.21	0.71	0.38	0.28	0.20	0.25
AB-3-2013-39	1.40	0.83	106	0.77	0.78	0.43	0.36	0.38	0.45	0.33	0.48	0.18	0.23	0.93	0.36	0.32	0.43	0.34
AB-3-2013-18	1.77	0.66	0.98	0.83	0.86	0.52	0.31	0.35	0.44	0.28	0.40	0.17	0.24	0.85	0.40	0.34	0.30	0.21
AB-3-2013-40	1.48	0.76	1.12	0.90	0.88	0.56	0.37	0.50	0.49	0.25	0.38	0.18	0.21	0.90	0.37	0.33	0.22	0.22
TF-2013-2-04	1.40	0.82	1.14	1.17	0.72	0.48	0.42	0.46	0.40	0.22	0.36	0.20	0.22	0.87	0.38	0.30	0.21	0.20
TF-2013-2-15	1.43	0.74	1.16	1.16	0.68	0.53	0.35	0.39	0.47	0.20	0.32	0.20	0.21	0.95	0.36	0.30	0.22	0.25
AB-3-2013-51	1.58	0.68	1.02	1.22	0.72	0.50	0.38	0.33	0.48	0.22	0.34	0.17	0.22	0.88	0.30	0.34	0.27	0.32
TF-2013-1-21	1.43	0.74	1.08	0.98	0.74	0.47	0.40	0.41	0.42	0.28	0.40	0.16	0.24	0.86	0.33	0.28	0.45	0.32
TF-2013-2-16	1.56	0.67	1.14	0.78	0.86	0.53	0.30	0.35	0.42	0.31	0.44	0.16	0.22	0.82	0.32	0.30	0.31	0.52
TF-2013-2-11	1.70	0.60	0.96	0.74	0.82	0.49	0.38	0.34	0.35	0.27	0.42	0.18	0.24	0.83	0.36	0.26	0.38	0.61
TF-2013-2-2	1.58	0.68	1.10	0.80	0.88	0.51	0.37	0.41	0.43	0.21	0.40	0.17	0.26	0.88	0.38	0.30	0.33	0.52
TF-2013-2-9	1.46	0.72	1.04	0.68	0.68	0.63	0.41	0.38	0.38	0.25	0.58	0.12	0.24	0.88	0.37	0.32	0.31	0.52
AB-3-2013-35	1.63	0.64	1.20	0.72	0.72	0.58	0.36	0.25	0.32	0.30	0.50	0.11	0.22	0.86	0.40	0.38	0.32	0.41
AB-3-2013-48	1.42	0.72	1.06	1.10	0.68	0.56	0.35	0.35	0.36	0.28	0.47	0.14	0.20	0.84	0.41	0.26	0.38	0.39
AB-3-2013-17	1.76	0.68	1.04	1.06	0.72	0.48	0.38	0.41	0.35	0.37	0.46	0.15	0.21	0.72	0.37	0.28	0.35	0.37
TF-2013-1-35	1.59	0.82	1.08	1.12	0.84	0.48	0.36	0.39	0.48	0.22	0.43	0.14	0.24	0.65	0.35	0.30	0.34	0.34
TF-2013-1-19	1.43	0.74	1.10	1.11	0.82	0.47	0.37	0.41	0.42	0.30	0.42	0.11	0.22	0.88	0.34	0.28	0.27	0.47
AB-3-2013-4	1.46	0.76	1.08	0.98	0.78	0.50	0.35	0.33	0.45	0.31	0.41	0.11	0.20	1.00	0.34	0.25	0.35	0.37
AB-3-2013-44	1.40	0.68	1.15	1.03	0.72	0.51	0.33	0.37	0.30	0.28	0.44	0.16	0.21	1.01	0.32	0.28	0.31	0.60
TF-2013-2-3	1.55	0.72	1.06	1.22	0.70	0.52	0.38	0.61	0.31	0.27	0.36	0.07	0.26	0.64	0.33	0.26	0.32	0.37
TF-2013-1-20	163	0.66	1.12	0.97	0.76	0.56	0.42	0.35	0.40	0.30	0.38	0.18	0.21	0.88	0.35	0.24	0.21	0.33
AB-3-2013-21	1.75	0.80	1.18	0.68	0.74	0.48	0.31	0.42	0.41	0.25	0.45	0.20	0.21	0.86	0.30	0.28	0.31	0.52
AB-3-2013-1	1.60	0.72	1.06	0.70	0.71	0.47	0.36	0.47	0.43	0.24	0.42	0.18	0.23	0.90	0.37	0.31	0.38	0.45

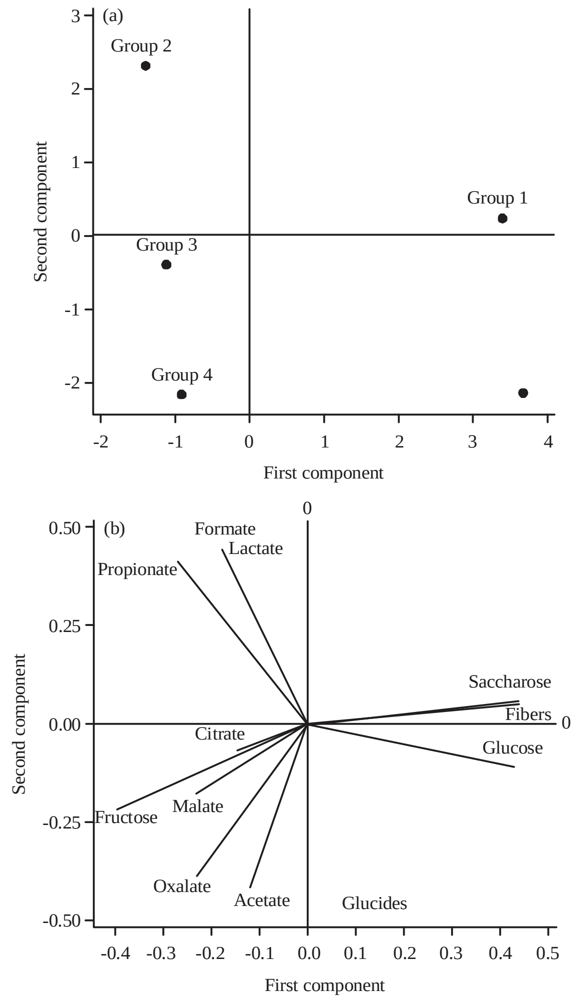

Fig. 4: Relationship between groups of maize and variables measured from a Principal Component Analysis (PCA)

good storage of maize requires grain moisture less than 14% because low water content reduces the risk of deterioration and microbial growth[19-21]. Thus, it appeared that among the groups obtained, only the varieties of group 2 were more suitable for good storage because of their lower moisture contents.

The total carbohydrates are the most important fraction of the dry matter of maize. The results obtained showed that the varieties of groups 1, 4 and 5 had the highest contents in total carbohydrates while varieties of group 2 contained the lowest rates. But overall, these levels of total carbohydrates determined (76.47-80.65 g/100 g dm) on samples analyzed were higher than those of 66-70.4 g/100 g dm obtained for maize varieties produced in Guatemala[22] and that of the variety disseminated by IITA in Nigeria (74.43 g/100 g) reported by Edema *et al.*[23] but lower than that obtained by Guria[24] for maize varieties cultivated in India (about 85 g/100 g). Carbohydrates are mainly stored as starch in cereal grains. They also act as natural laxatives, facilitating digestion and are the energy source used primarily by body[25,26]. High level of carbohydrates is associated with the starch content which represents about 68 g/100 g. The relatively high content in total carbohydrate is an asset to the use of maize varieties studied in the manufacture of commercial products such as starch, glucose and alcohol. The primary function of carbohydrates is energy production, accounting for 44% of total energy supply (excluding alcohol) in France, which ranks them before fats (38.5%) and protein (17.5%). The energy contribution of carbohydrate ranged from 40-80% depending on the country; the maximum rates generally occurring in the poorest and most rural areas, where the food is largely based on cereals. Carbohydrates played also a vital role, both in terms of food taste and pleasure of eating and metabolic and digestive functions or in food processing and storage[27]. They are involved in the control of glycaemia and insulin metabolism, in protein glycosylation or in the metabolism of cholesterol and triglycerides. Carbohydrates also act at the level of digestion, by influencing intestinal transit and by stimulating the growth of the microflora[28].

The protein contents of 30 maize varieties studied were between 9.50 and 14.34 g/100 g. These protein contents were largely above those of maize varieties produced by the National Centre for Agricultural Research (CNRA) and regenerated at the experimental station of Anguédédou in Ivory Coast[29]. They were also very close to the values reported in sorghum (10.4%), wheat (11.6%) and common millet (12.5%) by FAO[30]. Among the varieties studied, only Tchikoun variety (TF 2013-2-11) of group 5 showed the highest protein content. The protein content of cereals is influenced by both genetic and environmental factors[31,32]. As observed for other cereals such as sorghum, wheat and common millet, varieties of group 2 and 5 are good sources of vegetal protein and could be used as alternative sources of protein especially in developing countries like Benin where the food of the majority of the population is consisted mainly of starchy food and cereals[30]. Variety Tchikoun (TF 2013-2-11), owing to its protein content could have many benefits by providing vital constituents to the body, participating in upkeep of the balance of blood fluids, synthesis of hormones and enzymes and the contribution to immune function[33]. The essential function of protein is to meet the needs of the body in nitrogen and essential amino acids, because the quality of a protein is based on its composition in essential amino acids[30]. Regarding the amino acids profile, the predominant one detected in the maize varieties samples was glutamic acid while the least amino acid was methionine (Table 8). The values obtained in this study for the amino acids contents are similar to those reported by other authors, which were ranged between 1.67 and 2.17 mg/100 g crude protein for glutamic acid[34]. According to Zuraini *et al.*[35] amino acids are important components for healing and protein synthesis processes; any deficiency in these essential amino acids will hinder the recovery process. In addition, glycine together with other essential amino acids such as alanine, arginine and phenylalanine form a polypeptide that will promote growth and tissue healing[36]. The ash content of variety of group 4 is the lowest and significantly ($p<0.05$) different from those of varieties of group 3 which had the highest content but was similar to the ash content of varieties of other groups. Overall, the ash content obtained (1.22-3.18 g/100 g dm) was higher than those reported by Deffan *et al.*[29] (1.3 and 1.74 g/100 g) in improved and local maize varieties, respectively. However, the ash content obtained for varieties of groups 1, 2 and 5 were similar to those reported by Deffan *et al.*[29]. These results are also consistent with those of Squibb *et al.*[37] who reported that the ash content in maize was about 1.3 g/100 g. The difference in ash contents between the varieties studied could be explained by the environmental factors.

The determination of fat levels has permitted to assess the energy reserves of maize varieties. Varieties of group 5 had lower fat contents than the varieties of groups 1 and 2. The fat contents depend on the type of variety and therefore genetic factors. Fat content observed in this study ranging from 3.2-7.2 g/100 g were similar to those observed by Deffan *et al.*[29] who found values between 3.4 and 6 g/100 g in maize varieties produced by the National Centre for Agricultural Research (CNRA) of Ivory Coast. In general, the cereal grains are good source of essential fatty acids which are concentrated in the germ[38]. These essential fatty acids are important for the maintenance of cells in the body, protects the nervous system and also help fight against blood cholesterol[39]. The fiber contents of varieties of group 5 were the lowest and significantly ($p<0.05$) different from those of varieties of groups 1, 2, 3 and 4 which had the highest contents. These values are closed to the range of 2-2.5% found by Inglett[40] and Watson[41]. Dietary fibers help to regulate intestinal transit of food ingested by increasing the food bowl and consistency of the feces due to their ability to absorb water[42].

Simple carbohydrates include sugars (glucose, fructose, sucrose etc.) and oligosaccharides (Raffinose, starchyoseetc.)[43]. They are found almost exclusively in foods of plant origin and only in very small amounts in animal products. Sugar is a common trivial component of human food and is consumed daily by most men[44]. The present study showed that the varieties of group 1 were rich in sucrose, raffinose and glucose; the varieties of in group 2 had the high content of propionate and fructose as well as varieties of group 3 with high citrate and malate contents. As for those of group 4, they were rich in oxalate and acetate (Table 7). The raffinose, sucrose, glucose and fructose contents varied between 0.03 and 0.35%, 0.04 and 1.31, 0.07 and 0.17 and 0.04% and 0.06%, respectively.

Most organic acids (acetate, citrate, oxalate, lactate etc.) are bound to certain minerals such as calcium and magnesium for the formation of calcium and magnesium salts[45]. Oxalate content of the analyzed samples varied between 0.15 and 0.61%. Oxalates are considered as end-products of the metabolism of many tissues, leaves and roots[46]. Oxalic acids form soluble salt in water with ions such as Na^+, K^+, NH_4^+ and can also be bound to the Ca^{2+}, Fe^{2+} and Mg^{2+} thereby making these minerals unavailable. The citrate contents of maize varieties studied was about $0.04\pm0.01\%$; yet citrate increases aluminum absorption in the gastrointestinal tract. Thus, patients with kidney failure and taking aluminum phosphate should avoid taking calcium citrate[45]. Calcium acetate is used in the treatment of hypocalcemia and the calcium deficiency resulting from a food deficit or aging; on the other hand, magnesium acetate is used as a source of magnesium ions in the treatment of deficiencies and hypomagnesemia. Some calcium salts are used for specific practices[45]. The acetate content varies from 0.03-5.33% among the maize varieties investigated. Acetate or calcium carbonate are bound effectively to phosphate and are used orally to reduce intestinal absorption of phosphate in patients with hyperphosphatemia; this is particularly effective for patients with chronic kidney disease in order to prevent renal osteodystrophy development. Calcium carbonate, administered orally, is also widely used for its anti-acid properties[45]. Therefore, the variety Tchikoun (TF 2013-2-11) of group 4 could be recommended to people suffering from hypocalcemia and hypomagnesemia.

CONCLUSION

The 30 maize varieties investigated were grouped into 5 clusters according to their macro nutrient composition and 4 clusters based on their sugar and organic acids profile. Among these 30 varieties, only 9 were good source of protein while all of them were good sources of energy owing to their total carbohydrate content. Although this study has pointed out a good nutritional potential for some varieties, further investigation on the processing techniques that can preserve the nutritional value of those varieties is required to ensure food security in Benin and all West Africa region.

SIGNIFICANCE STATEMENT

The study established the nutritional composition of maize varieties consumed in the southern region of Benin. All the varieties were good source of energy owing to their total carbohydrate content while only nine of them were good source of protein.

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