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Evaluation of mineral composition of endogenous and improved varieties of maize (*Zea mays*) cultivated in Southern Benin

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This study aims to establish the mineral potential of 30 varieties of corn mainly used in the traditional and industrial processing sectors. The samples were collected from all agro-ecological zones of corn production in southern Benin. The nutritional profile of samples was evaluated through their mineral composition using AOAC methods. The results of cluster analysis revealed that the samples analysed were ranked in three groups consisting of fairly homogeneous varieties. The results also showed that the 30 varieties contained variable amounts of phosphorus, potassium, sodium, zinc, magnesium, calcium and iron. Varieties of cluster 1 were very rich in iron (710 ± 0.01 mg/kg), those of cluster 3 contained the highest potassium contents (7958 ± 0.1 mg/kg) while samples of cluster 2 contained the lowest contents in potassium (1883±0.02 mg/kg), sodium (213.40 ± 0.00 mg/kg), magnesium (352.10± 0.01 mg/kg) and calcium (93 ± 0.00 mg/kg). Moreover, Ca/P and Na/K ratios were 0.38 and 0.13 for cluster 1 corn varieties, 0.21 and 0.11 for cluster 2 samples, and 0.07 and 0.03 for cluster 3 varieties respectively. With the exception of cluster 3 samples that meet the nutritional requirement in iron and dietary intake of magnesium for children, the remaining maize varieties samples did not showed a satisfactory mineral composition.

Key words: Corn, mineral status, variety, Benin.

INTRODUCTION

Corn (*Zea mays* L.) is widely cultivated in Benin, and represents about 3/4 of the total country's cereal production (MAEP, 2010). It is cultivated in all the districts with variable importance, and remains the first cereal produced, followed by sorghum, rice and millet. Indeed, corn production increased from 230,000 tons in 1970 to 800,000 tons in 2000 and over to 1 345820 tons in 2013 (DPP, 2013). In this respect corn plays an important role in human diet in Benin, and it is used in various forms according to different destinations (Adégbola et al., 2011; Balogoun, 2012). Over 40% of the country's production is market at national level, and the main customers are the households and the urban food small craft industry (ONS, 2010). Exports to the neighboring countries are not recorded but represent significant amounts (Hell et al., 2000). Maize is mainly used as food and feed (poultry, pigs, cattle) and as raw material for some industries (brewing, soap and oil factories) (Boone et al., 2008). In Benin, corn is consumed in various forms and goes into preparation of several dishes. The average level of maize consumption in Benin is estimated to about 96 kg/capita /year (Gandonou et al., 2010), which places the country in the forefront of major consumers of corn in West Africa. Smith et al. (1997) predicted that corn will become a cash crop and will ensure food security better than any other culture. In Benin, farmers have a large range of corn varieties they cultivate and of which some are often oriented toward specific agro-food processing according to their technological characteristics. These corn varieties include both the local and the improved ones managed by farmers themselves. However, there is a lack of adequate information on the mineral composition (sodium, potassium, calcium, magnesium, zinc, iron, phosphorus, etc.) of most of these varieties of corn mainly consumed by the populations. So, there is a need to characterize these varieties of maize in order to enhance their contribution to food security. The present study aims to investigate the mineral composition of varieties of maize mainly used in southern Benin with the purpose of knowing which of them could be more encouraged for cultivation and consumption.

MATERIALS AND METHODS

Plant material used in the present study was composed of endogenous and improved varieties of maize (*Zea mays*) cultivated in the southern region of Benin. Grains were collected from farmers who provided information concerning the local name and the type (improved or local) of each variety (Table 1 and Figure 1).

Sampling of maize

The sampling was conducted in 12 municipalities located in the agro-ecological zones (AEZ) V, VI, VII and VIII according to (CIPB, 2007), where maize is mainly cultivated (Figure 1). A total of 30 samples of corn including seven improved and 23 local varieties were collected from producers randomly selected in the sampling zones. The samples were then transported to the laboratory, packaged in canvas bag and stored in cold room at 4°C.

Samples preparation

Samples of each variety of maize were crushed using a crusher (Falling Number, type 3600) and then ground with a laboratory mill (Retsch, Type Z M 1). The maize flours obtained were used for the determination of mineral elements.

Analysis of mineral elements

The first step of the determination of mineral elements was the mineralization of flours from each of 30 samples according to Hach (1999). Then, sodium, potassium, calcium and magnesium contents were determined using Atomic Absorption Spectrophotometry method (Atomic Absorption Spectrophotomer, Unicam ATI 929 s.a.a with flame). For the determination of phosphorus, iron and zinc, Molecular Absorption Spectrophotometry (Spectrophotometer DR 2800) was used.

Determination of sodium, potassium, calcium and magnesium contents

For mineralization, two g of corn flour was incinerated in a muffle furnace at 550°C for 24 h. The ash obtained was dissolved in 2 ml of hydrochloric acid solution 6N and then evaporated on a hotplate at 125°C. The viscous residue obtained was dissolved again and recovered in a 100 ml volumetric flask using nitric acid 0.1 M. The solution obtained was then diluted to determine the mineral elements in accordance with the standard EN 14082 (Hach, 1999).

Determination of iron, zinc and phosphorus contents

Known volume of the solution previously obtained was neutralized (pH between 4 and 5) by addition of 5N sodium hydroxide. The final volume was adjusted with distilled water to a known proportion. Then, ferrozine method 8147, zincover method 8009 and ascorbic acid method 8048 were used for the determination of iron, zinc and phosphorus contents respectively (Hach, 1999).

Statistical analysis

Cluster analysis (agglomerative hierarchical cluster; Ward's method) was computed using SAS software (version 9.2) in order to classify all the varieties in a more limited number of groups of relatively homogeneous items. Corn varieties groups obtained were subjected to analysis of variance (ANOVA). Means difference were determined using Student Newman Keuls (SNK) test, and significance of difference was established at $p < 0.05$. Clusters of corn varieties were then associated with different mineral elements through principal component analysis (PCA) using XLSTAT software (version 2011, Addinsoft, Paris, France).

RESULTS

The mineral contents of maize varieties analysed are summarized in Table 2. The data showed that phosphorus (P) and potassium (K) contents of samples varied from 51.04 to 4860.98 mg/kg and from 117 to 11949 mg/kg respectively. Sodium (Na), magnesium (Mg) and zinc (Zn) contents ranged between 104 -

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Table 1. Maize varieties (endogenous and improved) collected in study zones.

Sampling code	Varieties local names	Type	Sampling areas	Agro-ecological zones
TF2013-2-016	Gnonli	Local	Hounsa/Niaouli	VI
AB-3-2013-017	Tchigbadé	Local	Adjaïgbonou	VII
AB-3-2013-021	Tchankpo	improved	Adjaïgbonou	VII
TF2013-2-015	Gogodomé	Local	Hounsa /Niaouli	VI
TF2013-2-003	Ovinonboè	Local	Anavié/Houèzeto	VI
AB-3-2013-001	DMR-ESRW	improved	Covè	VI
AB-3-2013-048	Edouatchi	Local	Sèglahoué	VI
TF2013-2-009	Tchoké	Local	Dohinhonko	VI
TF2013-1-020	EVDT97 STR	improved	Ayihounzo	VI
AB-3-2013-043	Gotin-wlin	Local	Ahogbéya	VI
TF2013-1-019	Massahoué	Local	Vidjinan	VI
AB-3-2013-043	Gotin-wlin	Local	Ahogbéya	VI
TF2013-1-021	Massahoué	Local	Sémè	VI
TF2013-1-035	Akobi-gbadé	local	Kpankou	V
AB-3-2013-018	Edouanti	Local	Adjaïgbonou	VII
AB-3-2013-011	Sounwèkoun	Local	Lohounvodo	VIII
TF2013-2-002	Yagbo	Local	Anavié/Sèdjè	VI
AB-3-2013-044	Kpégladé	Local	Ahogbéya	VI
AB-3-2013-051	Acthivi or Ghana Baffokouin	Local	Gbenounkochihoué	VI
AB-3-2013-040	Carder/wilin-wilin	improved	Ahogbéya	VI
TF2013-2-011	Tchikoun	Local	Agonmey	VII
AB-3-2013-004	white	improved	Avlimè	VI
AB-3-2013-035	Carder	improved	Sènouhouè	VI
TF2013-2-004	Massahoué	Local	Anavié-Sèdjè	VI
AB-3-2013-009	Houévi	Local	Gbèdji	VI
TF2013-1-018	Tchahounkpo	Local	Vidjinan	VI
AB-3-2013-014	Sounaton-kouin	Local	Djèhadji	VIII
TF2013-2-010	Edouatin	Local	Dohinhonko /Sèkanmey	VI
AB-3-2013-053	Kpédévi-non-ovo	Local	Gbénounkochihoué	VI
AB-3-2013-014	Sounaton-kouin	Local	Djèhadji	VIII

295.48 mg/kg, 174 – 2759.28 mg/kg, and 52.05 –382.82 mg/kg respectively. Iron (Fe) contents varied from 151.06 to 976.36 mg/kg whereas for calcium (Ca) amounts ranging between 41.98 and 271 mg/kg were obtained (Table 2). The results of cluster analysis indicated that the maize varieties samples analysed were clustered into three different groups according to similarity in mineral composition (Figure 2). Cluster 1 is consisted of 7 varieties namely: TF-2013-2-016 and TF-2013-2-015 collected from Hounsa-Niaouli, TF-2013-2-004 (Anavié-sèdjè), AB-3-2013-021 (Adjaïgbonou), TF-2013-2-003 (Anavié-Houèzeto), AB-3 2013-035 (Sènouhouè) and AB-3-2013-009 (Gbèdji). Cluster 2 comprised 7 varieties including: AB-3-2013-017 from Adjaïgbonou, TF-2013-01-020 (Ayihounzo), AB-3-2013-039 (Agohoué), TF-2013-01-019 (Vidjinan), TF-2013- 01-021 (Sémè), TF-2013-2-010 (Dohinhonko/Sèkanmey) and AB-3-2013-053 (Gbénounkochihoué) while cluster 3 grouped 16 varieties: AB-3-2013-001 from Covè, TF-2013-2-009 (Dohinhonko), AB-3-2013-043 (Ahogbéya), AB-3-2013-004 (Houéyogbé), TF-2013-01-035 (Kpankou), TF-2013-2-011 (Agonmey), TF-2013-2-014 (Houèglé), AB-3-2013-014 (Djéhadji), TF-2013- 2-002 (Anavié-Sèdjè), AB-3-2013-018 (Adjaïgbonou), AB-3-2013-051 (Gbénounkochihoué), AB-3-2013-011 (Lohounvodo), AB-3-2013-044 (Ahogbéya), AB-3-2013-048 (Sèglahoué), AB-3-2013-040 (Ahogbéya) and TF2013-01-018 (Vidjinan). The analysis of variance showed that the three (3) clusters were different regarding the mineral contents of maize varieties comprising each cluster. The clusters were very significantly different ($p < 0.001$) when considering phosphorus (P), potassium (K), magnesium (Mg), zinc (Zn), calcium (Ca) and iron (Fe) contents, and highly different ($p < 0.01$) while considering Na content. Student Newman Keuls (SNK) test revealed that the varieties of cluster 3 had high contents in phosphorus (2310 ± 0.04 mg/kg), potassium (7958 ± 0.01 mg/kg), magnesium (1842 ± 0.12 mg/kg), zinc (270 ± 0.00 mg/kg) and calcium (166 ± 0.02 mg/kg), while those of group 1 contained the higher level of iron (375 ± 0.00 mg/kg).

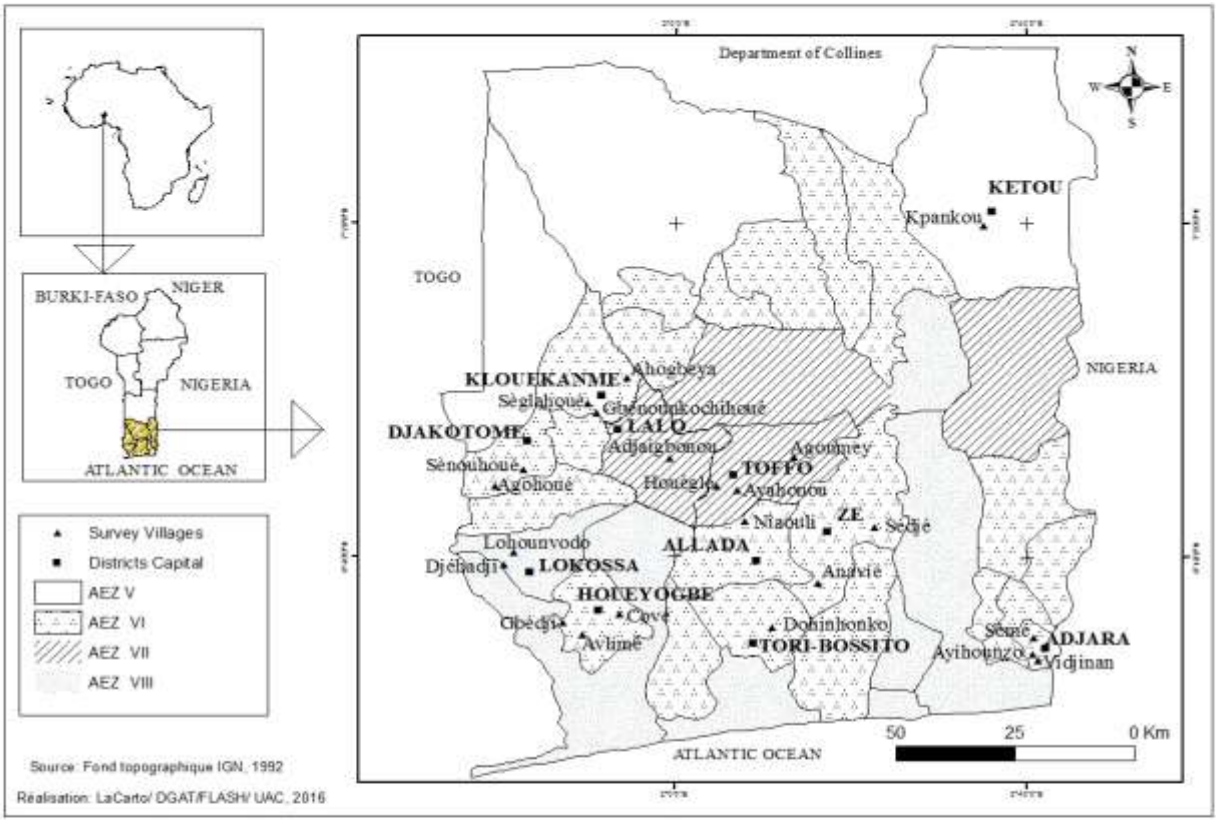

Figure 1. Map showing the sampling areas in southern Benin.

With regard to maize varieties of cluster 2, they contained the lowest contents in potassium (1883 ± 0.02 mg/kg), sodium (213.40 ± 0.00 mg/kg), magnesium (352.10 ± 0.01 mg/kg), iron (229.4 ± 0.00) and calcium (93 ± 0.00 mg/kg) (Table 3).

The principal component analysis (PCA) on corn groups and mineral contents resulted in two axes accounting for 100% of the total variation of which 70.1% was explained by the first axe (Axe 1) and 28.9% by the second axe (Axe 2) (Table 4 and Figure 3). The first axe opposes Na and Fe contents to Mg, Zn and Ca contents of maize varieties (Table 5 and Figure 3). This means that any maize varieties having high contents in Fe and Na, had low contents in Mg, Ca and Zn and vice-versa. Regarding the second axe, it opposes Zn content to Na and Fe contents (Table 4 and Figure 3). It's also appeared that corn samples having high content in Zn, had low contents in Fe and Na and vice-versa.

DISCUSSION

Several essential trace elements have effects on organisms functions (Sodipo et al., 2012). In addition, information of food composition data and its chemical components is important in nutritional planning and source of data for epidemiological studies (Ali et al., 2008). This study allowed to classify different corn varieties into three clusters consisting of relatively homogeneous items. Among the three clusters obtained, samples of cluster 3 contained higher level of P, K, Na, Mg, Ca and Zn, those of cluster 1 contained higher amount of Fe, while samples of cluster 2 were poor in Fe (Table 3). The average of phosphorus content of cluster 3 samples was 2310 ± 0.04 mg/kg. This results agree with the findings of Nago (1997) (2360-3490 mg/kg), but comparatively higher than the value of 0.1 mg/kg found by Adeoti et al. (2013) and lower than 200 000 mg/kg reported by Sule Enyisi et al (2014). The recommended daily intake of phosphorus for adults and children is 8000 mg/kg per day (Pillai and Nair, 2013). Phosphorus associated with calcium, helps to strengthen bones and teeth, especially with children and nursing mothers (Andzouana and Mombouli, 2012). The average phosphorus content obtained for varieties of cluster 3 was lower than the recommended standard. Therefore the varieties of cluster 3 were not the best corn for phosphorus intake despite being richer in phosphorus than the varieties of clusters 1 and 2. The average potassium content in samples of cluster 3 (7958 ± 0.09 mg/kg) was 4.7 times higher than that of cluster 1 (2033 ± 0.02 mg/kg) and three times higher than that of cluster 2 (1883 ± 0.02 mg/kg). However, this level of potassium in cluster 3 samples is lower than the value of 90 000 mg/kg

Table 2. Mineral elements contents of maize varieties samples collected.

Sampling code	Mineral contents (mg/kg)						
	P	K	Na	Mg	Ca	Zn	Fe
TF 2013-2-016	86.37	1359.98	247.53	402.88	69.60	84.06	976.36
AB-3-2013-17	122.82	1146.14	254.22	305.37	41.98	52.05	200.00
AB-3-2013-21	812.54	3633.02	260.91	630.39	124.84	84.06	904.60
TF-2013-2-15	74.47	1906.46	258.68	467.88	152.46	62.72	545.77
TF-2013-2-03	281.42	1724.3	264.25	500.39	124.84	94.73	474.00
AB--2013-001	1244.76	4583.42	282.095	971.67	180.08	126.74	438.12
AB-3-2013-48	2741.88	10800.62	276.52	2336.75	97.22	116.07	402.24
TF 2013-2-009	1384.08	5985.26	266.48	1377.94	124.84	126.74	366.35
TF 2013-01-20	186.26	1961.9	248.64	386.63	97.22	137.41	330.47
AB-3-2013-39	339.57	1312.46	247.53	386.63	69.60	233.44	151.06
TF 2013-01-019	51.04	1581.74	247.53	321.63	97.22	286.79	186.94
AB-3-2013-43	1946.11	6104.06	250.87	1605.45	152.46	265.45	330.47
TF 2013-01-021	779.26	2801.42	253.10	695.40	97.22	244.11	294.59
TF 2013-01-35	2426.81	6959.42	257.56	1686.71	207.70	265.45	330.47
AB-32013-018	4274.53	11473.82	272.06	2483.00	180.08	329.47	402.24
AB-3-2013-011	4065.22	11949.02	257.56	2759.28	152.46	308.13	474.00
TF 2013-2-002	2803.95	9747.26	263.14	2580.51	124.84	265.45	438.12
AB-3-2013-44	4530.71	11806.46	264.25	2743.00	124.84	276.12	402.24
AB-3-2013-51	4860.98	10079.9	277.63	2613.00	152.46	361.48	366.35
AB-3-2013-040	74.47	11861.9	295.47	2743.00	152.46	372.15	402.24
TF 2013-2-011	2008.18	8068.22	274.29	2158.00	180.08	382.82	366.35
AB-32013-004	2217.50	7078.22	269.83	1621.71	124.84	212.10	366.35
AB-3-2013-035	247	1986	264	484	125	73	653
TF 2013-2-004	186	1724	265	419	70	73	761
AB-3-2013-09	117	1899	263	338	125	95	653
TF 2013-1-018	1259	1714	247	676	271	300	303
TF 2013-2-14	841	1570	257	745	213	250	253
TF 2013-2-10	1425	2513	104	174	114	110	189
AB 3-2013-53	209	1867	138	195	132	250	254
AB 3-2013-014	273	7540	237	375	220	360	360

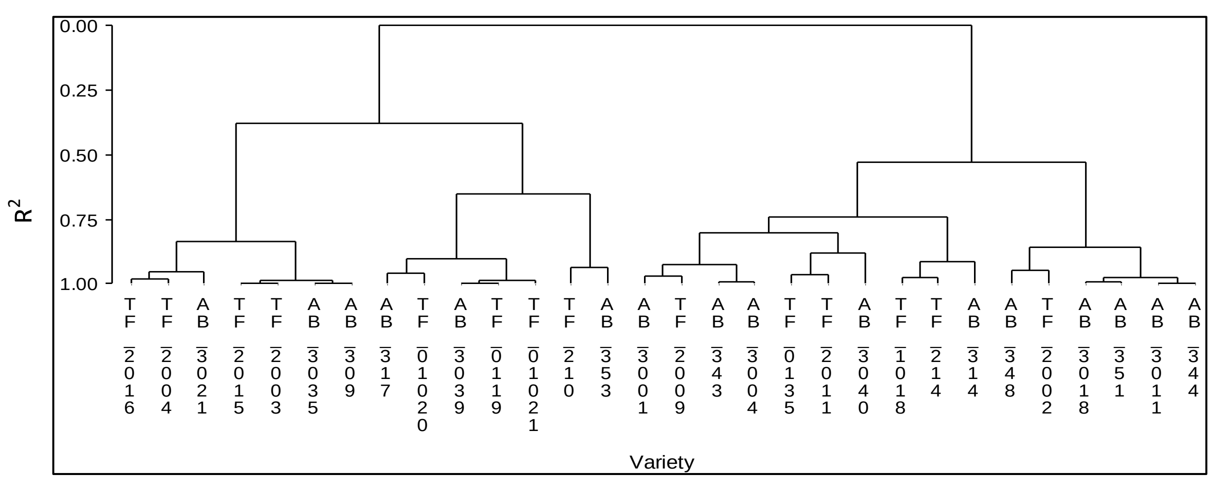

Figure 2. Agglomerative cluster analysis dendrogram for clustering maize varieties samples (n=30) into groups of similar mineral profile.

Table 3. Quantitative contents (mean ± standard deviation) of mineral elements associated with different groups of maize varieties.

Mineral elements	Mineral contents (mg/kg)			F	CV
	Cluster 1	Cluster 2	Cluster 3		
Phosphorus (P)	300±0.01b	445±0.02b	2310±0.04a	10.99***	91.87
Potassium (K)	2033±0.03b	1883±0.02b	7958±0.1a	20.16***	37.07
Sodium(Na)	261±0.00a	213.4±0.00b	266±0.00a	6.72**	12.55
Magnesium (Mg)	463±0.00b	352.1± 0.01b	1842±0.12a	19.99***	37.90
Zinc (Zn)	81±0.00c	188±0.00b	270±0.00a	14.85***	31.26
Calcium (Ca)	113±0.00b	93±0.00b	166±0.02a	10.11***	28.77
Iron (Fe)	710±0.01a	229.4±0.00c	375±0.00b	43.51***	22.94
Ca/P	0.38	0.21	0.07	-	-
Na/K	0.13	0.11	0.03	-	-

**: P < 0.01; ***: P < 0.001. [a, b]: Means with the same letters in a row are not significantly different (P > 0.05).

Table 4. Eigen value of the first three principal components.

PCA axes	Eigen value	Proportion	Cumulative proportion
PC1	4.9773	0.711	0.711
PC2	2.0227	0.289	1.000
PC3	0	0	1

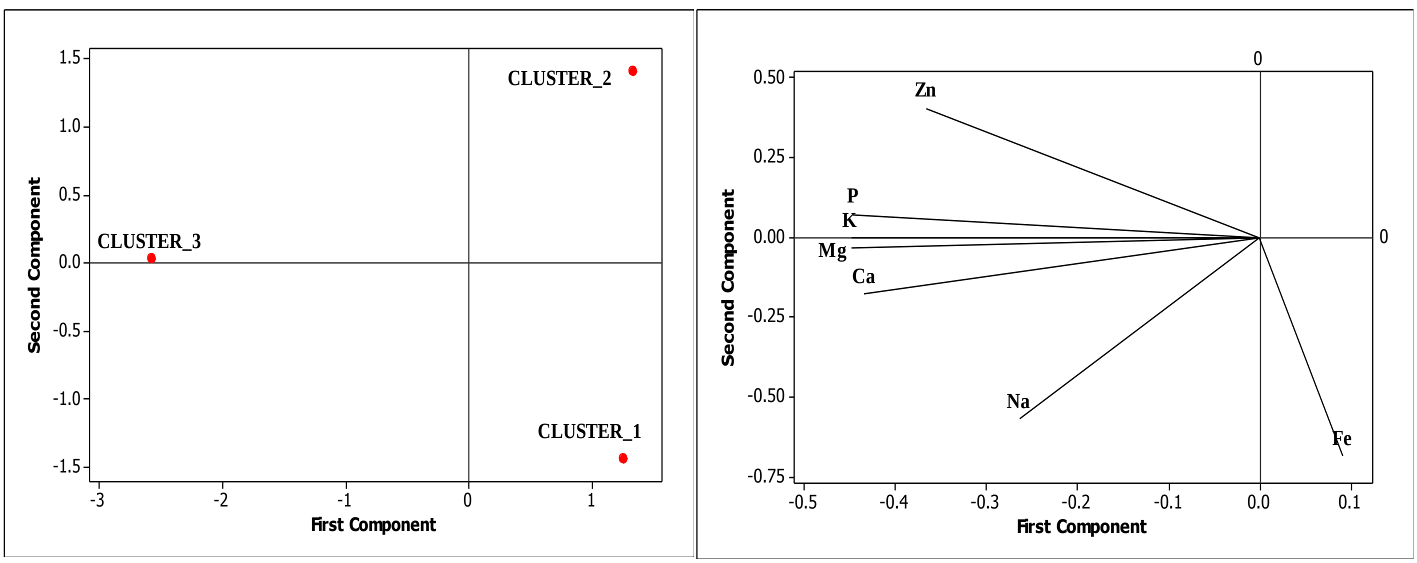

Figure 3. Principal Component Analysis (PCA) to reveal linkage between groups of corn and mineral elements analysed on axes 1 and 2. P: Phosphorus; K: Potassium; Na: Sodium; Mg: Magnesium; Zn: Zinc; Ca: Calcium; Fe: Iron.

reported by Sule Enyisi et al. (2014). Moreover, when comparing the potassium content of varieties under study to the mineral contents of other cereal such as millet (3300-3700 mg/kg) (Békoye, 2011), the cluster 3 varieties could be considered as very good sources of potassium. Sodium is an important mineral that contributes to the regulation of blood flow and holding potential of electrons in body tissues (Alinnor and Oze, 2011). The average sodium contents in maize varieties of clusters 1, 2 and 3 were 261 ± 0.00 mg/kg, 213.4 ± 0.00 mg/kg and 266 ± 0.00 mg/kg respectively. These levels of sodium contents were lower than the reported values of 594 mg/kg (FAO, 1993) and 1000 mg/kg (Enyisi et al., 2014), but higher than 178.6 mg/kg found by Adeoti et al. (2013).

Table 5. Variables associated to the first two components.

Variable	PC1	PC2
P	-0.446*	0.071^{ns}
K^+	-0.448*	-0.002^{ns}
Na^+	-0.264^{ns}	-0.569*
Mg^{2+}	-0.448*	-0.034^{ns}
Zn^{2+}	-0.366*	0.406*
Ca^{2+}	-0.434*	-0.177^{ns}
Fe	0.092^{ns}	-0.688*

*: P < 0.05; ns: not significant at 5%.

Therefore, the flours from maize varieties of clusters 3 are significant sources of sodium and could be recommended for pregnant women and those with hypertension and kidney diseases of whom the direct consumption of salt should be minimized (Emebu and Anyika, 2011). In addition, cluster 3 samples showed the higher content in zinc, followed by cluster 2 and cluster 1 varieties (Table 3). According to Sandstead et al. (1998), zinc is very useful for protein synthesis, cell division, cell maturation, immunity and sexual function. In the same way, the samples of cluster 3 had the higher content in magnesium, followed by samples of clusters 1 and 2. The recommended dietary intake of magnesium is 3500 mg/kg for adults and 1700 mg/kg for children (Alinnor and Oze, 2011). Based on the results concerning the magnesium content of corn varieties analysed, we can conclude that only the samples of cluster 3 had magnesium content that meet daily needs of children. According to Alinnor and Oze (2011), magnesium plays a vital role in calcium metabolism and bone formation and is also involved in the prevention of diseases related to the circulatory system. It also helps to regulate blood pressure and secretion of insulin. The average calcium contents of samples of clusters 1, 2 and 3 were 113, 93 and 166 mg/kg respectively (Table 3). These values are in agreement with the findings of Nago (1997) (49-159 mg/kg) but were comparatively higher than 10 and 100 mg/kg found respectively by Adeoti et al. (2013) and Sule Enyisi et al. (2014), and lower than data reported by FAO (1993) (483 mg/kg) for maize and millet (300-400 mg/kg) (Békoye, 2011). The recommended daily intake of calcium stipulated by the World Health Organization of the United Nations (WHO) is 8000 mg/kg for adults and children. This study showed that the calcium contents in all the varieties of corn studied were below the standard recommended by WHO. Calcium is the most abundant mineral in the human body and is involved in blood clotting, muscle contraction, neurological function, formation of bones and teeth (Senga Kitumbe et al., 2013). It is also an important factor in the enzymatic metabolic processes (Karau et al., 2012). The iron contents in corn varieties of three clusters were largely above the daily level recommended by WHO which is 100 to 150 mg/kg (Senga Kitumbe et al., 2013). According to Andzouana and Monbouli (2012), iron as oligo-element, plays many biochemical roles and constitutes a fundamental element in the metabolism of all living organisms. In human, iron is an essential component of many types of proteins and enzymes (Andzouana and Monbouli, 2012). Therefore, corn varieties investigated meet the nutritional requirement in iron if consumed reasonably.

The ratios of calcium to phosphorus (Ca/P) and sodium to potassium (Na/K) were presented in Table 3. According to Shills and Young (1988) diets rich in protein and phosphorus may promote the loss of calcium in the urine; this had led to the concept of the Ca/P ratio (Adeoti al., 2013). The Ca/P values were 0.38, 0.21 and 0.07 for clusters 1, 2 and 3 samples respectively. Ca/P ratio greater than 2 contributes to increase the absorption of calcium in small intestine (Adeyeye and Aye, 2005; Alinnor and Oze, 2011). Furthermore, food is considered as good if Ca/P ratio is greater than 1 and poor if this ratio is less than 0.5 (Alinnor et Oze, 2011). Consequently, the 30 maize varieties cannot be considered as good source of mineral since the Ca/P ratios were lower than 0.5 for all of them (Table 3). The Na/K ratios of cluster 1, cluster 2 and cluster 3 were 0.13, 0.11 and 0.03 respectively (Table 3). According to Alinnor and Oze (2011), Na/K ratio is of great importance for prevention of high blood pressure. Indeed, Na/K ratio helps to control blood pressure and food having a Na/K ratio less than 1 lowers blood pressure. Thus, flour obtained from the 30 maize varieties investigated would probably reduce the risk of high blood pressure.

The 30 samples analysed were collected in four agro-ecological zones representative of all agro-ecological zones of maize production in Benin (Figure 1). All the four zones have the same climate (sudano-guinean) with an annual rainfall ranging between 800 and 1400 mm/year (MEPN, 2008). However, it appeared through the analytical data that maize varieties of cluster 3 collected from agro-ecological zones V (cotton culture zone),VI (bar ground zone) and VII (depression zone) showed the higher contents in phosphorus, potassium, magnesium, zinc and calcium. In addition, in these three areas corn is usually cultivated in association with other crops such as legume plants, and tuber and to a lesser extent cotton (MEPN, 2008). Based on these observations we can conclude that ecological conditions of production areas may have an impact on the mineral composition of corn varieties as reported by Hussaini et al. (2008) and Saïdou et al. (2012).

Conclusion

This study revealed the mineral potential of 30 corn varieties produced in Southern Benin. The results showed that the 30 corn varieties can be divided into three groups based on their mineral composition profile. With the exception of iron, cluster 3 corn varieties contained the highest mineral contents whereas cluster 2 samples showed the lowest levels of potassium, magnesium, zinc and iron. In return, cluster 1 varieties contained the highest amount of iron but very poor in zinc. Based on the results obtained, some of the studied maize varieties could be considered as complementary sources of mineral in spite of their ratios of calcium to phosphorus were lower than 1. Thus, when consumed frequently, they can help to meet the daily recommendations of essential mineral nutrients and improve the nutritional status of rural and urban populations.

Conflict of Interests

The authors have not declared any conflict of interests.

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