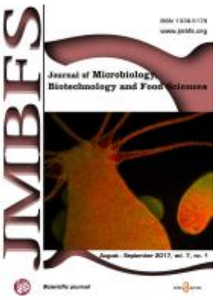

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NUTRITIONAL VALUE AND PHYSICOCHEMICAL COMPOSITION OF PEARL MILLET (*PENNISETUM GLAUCUM*) PRODUCED IN BENIN

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ABSTRACT

The high prices of animal foods and limited income earned in developing countries have resulted in their dependency on cereal-based preparations as staple food. Cereals such as maize, sorghum or pearl millet are often used in the production of various traditional foods and beverages in many African countries including Benin. In the republic of Benin, the nutritive value of cereals such as maize and sorghum is well documented. However, the nutritional value of pearl millet varieties produced in Benin remains to be investigated. The aim of this study was to assess the nutritional value of 22 varieties of pearl millet produced in Benin. After samples collection, the pearl millet grains were milled into fine powder and their compositions in six minerals (Na^{+}, K^{+}, Ca^{2+}, Mg^{2+}, Fe^{2+}, Zn^{2+}) and proximate (ash, dry matter, starch, protein, total and reducing sugars) were determined using standard analytical AOAC methods. Next, we assessed the relationship between these variables using the Pearson Correlation Analysis (PCA). We found that protein, total and reducing sugars levels varied widely (ranged from 1.86 to 93.4 mg/g, 178.64 to 652.54 mg/g and 16.62 to 174.22 mg/g, respectively). Additionally, we found a highly significant correlation ($P<0.001$) between levels of starch and amylose. Mineral levels also varied widely, with some millet cultivars being particularly enriched in iron and magnesium (levels ranged from 13.85 to 2766.31 mg/kg, and from 340.27 to 4769.9 mg/kg, respectively). Four groups of pearl millet can be distinguished based on data from the PCA: iron-rich millets (group G1), carbohydrate-rich millets (group G2), and two less nutritious millets (groups G3 and G4). This study opens new avenues for millet fortification and provides opportunity to increase farmers' awareness in selecting pearl millet varieties for reducing malnutrition.

Keywords: Pearl millet, nutritional value, physicochemical composition, food security, Benin

INTRODUCTION

Africa is the center of origin and a major producer of several cereals (Macauley, 2015). Cereals are the major dietary energy supplies and are consumed in a variety of form depending on the ethnic or religious affiliation (Idem and Showemimo, 2004)**.**The important cultivated cereals crops in Africa are maize, millet, rice, sorghum and wheat (Macauley,2015). Pearl millet (*Pennisetum glaucum*), a hardy cereal crop compared with wheat (*Triticum aestivum*) and rice (*Oryza sativa* L.), is grown in regions characterized by relatively low rainfall owing to its ability to tolerate and survive under continuous or intermittent drought conditions (**Jain and Bal, 1997**). It is a drought tolerant cereal crop grown primarily as a food grain in India and Africa **(Dykes and Rooney, 2007**; **Hoover et *al.*, 1996)**. Because of its good performances in low-fertility soils such as semi-arid regions of Africa and Southeast Asia, Pearl millet is an important staple cereal cultivated in regions severely affected by malnutrition. It has a high nutritional value compared to others cereals and presents therefore a high potential in contributing to food and nutrition security (**Shweta, 2015**). The cultivated area of millet on the African continent was estimated to 19,998,008 hectares, with annual production reaching 16,008,838 tons (**FAO, 2015; Macauley and Ramadjita, 2015**). Pearl millet production ranked third among cereals in Africa. In Benin, the national production (27000 tons in 2013, **USDA 2013**) ranks fourth among cereals after rice, maize and sorghum. Importantly, its production ranks second in the Northern part of the country, and could therefore be a potential target for studying diversity of millets produced within Benin. Being a drought-tolerant crop, pearl millet is cultivated in the dry Northern regions of Benin under increasingly short and marginal raining seasons. It is used in various local food preparations like local porridge, cakes and traditional beverages.

Previous studies showed that millet has several potential health benefits, partly attributed to its polyphenol and dietary fiber contents (**Devi et *al.*, 2014**). Depending on the country, millet is sometimes used directly in preparations (**Adebiyi et *al.*, 2016**) or mixed with other grains like sorghum or cowpea in order to improve the nutritional quality of food (**Modu et *al.*, 2010; Almeida-Dominguez et *al.*, 1993**;). In Burkina-Faso for example, it is used as complementary food for young children when pearl millet is fermented (**Songré-Ouattara et *al.*, 2009, 2008; Tou et *al.*, 2006)**. The importance of this crop for developing countries incited biotechnologists to converge their attention on the improvement of some species of millet (**Kothari et *al.*, 2005**). On the other hand, epidemiological studies have demonstrated that regular consumption of whole grain cereals and their products can protect against the risk of cardiovascular diseases, type II diabetes, gastrointestinal cancers and a range of other disorders (**McKeown et *al.*, 2002***)*.

Although many studies have been conducted on the plants and grains, the assessment of the nutritional factors of pearl millet varieties produced in Benin has not been performed. Furthermore, pearl millet varieties cultivated in Benin are not well documented. We devised this study to understand to what extent intake of pearl millets could contribute to food security in the Northern Benin. The aim of our study was to determine concentrations of six selected minerals (iron, zinc, magnesium, calcium, potassium) and proximate compositions of 22 varieties of pearl millet produced in Benin.

MATERIAL AND METHODS

Samples collection

A total of 22 cultivars of pearl millets were collected from two regions of Northern part of Benin Republic (Atacora-Donga and Borgou-Alibori). Following collection, the grains were washed thoroughly to remove any debris or dust particles, milled into fine powder using house blender. Table 1 presents the cultivars description along with their vernacular names and the names of the sites (villages) of provenance.

Table 1 List of pearl millet samples collected

Samples order	Region of Benin	Vernacular name	Collecting site	Samples code
1	Atacora-Donga	*Eyémata*	Manta (kouwinkou)	CA
2		*Amala korolomè*	Sosso II	CB
3		*Sowariya*	Boribansifa	CC
4		*Zokpéra*	Tanéka-koko	CD
5		*Eyomata*	Pam-Pam	CE
6		*Amala koukpêtè*	Katanga	CF
7		*Zokpéra*	Barèï	CG
8		*Diyématrie*	Kouwotchirgou	CH
9		*Sowariya*	Yinréboudé	CI
10		*Amala Kouhouloumè*	Sosso II	CJ
11		*Amala koukpêtè*	Sosso II	CK
12		*Yomaga*	Tampatou	CL
13	Borgou-Alibori	*Iyaku*	Goun-Goun	CM
14		*Hinnitchiré*	Karimama centre	CN
15		*Guero*	Diapéou	CO
16		*Idié*	Goumori	CP
17		*Wea*	Kalalé centre	CQ
18		*Eyomata*	Boérou	CR
19		*Meïwaré*	Wanrarou	CS
20		*Gbéï*	Sinendé centre	CT
21		*Sonna*	Bodjekali	CU
22		*Iyasé*	Goun-Goun	CV

Proximate composition analysis

Proximate composition analysis consists of evaluation of proteins, total and reducing sugar, starch and amylose content according to the standard procedures of official method of analysis of the Association of Official Analytical Chemists (**AOAC, 2000**). The protein (total nitrogen) content was determined by Kjeldahl method using 6.25 as conversion constant. The total sugars were measured by spectrometry method at 492 nm using D-glucose as standard. Reducing sugars were also measured by spectrometry (Thermo Scientific Spectrophotometer, Biomate 3S, number 335904 series, 2004) method with a reagent 3.5 dinitrosalicylic acid (DNS) at 546 nm using maltose as standard. Starch content was determined by reading solution floated after preparing the (hydrolysis of starch) medium using the different pearl millet flour sample, sodium hydroxide (1 M) and chlorhydric acid (1 M) at 580 nm using BioMate™ 3S Spectrophotometer.

Mineral composition analysis

The minerals such as calcium were determined from an aliquots of the solutions obtained from ash by established flame Atomic Absorption Spectrophotometry procedures (mineralization, calibration and dosage, 2003) as described by **Kouassi et al. (2013)**. Solution was prepared for each sample of variety. The sodium (Na^+) and potassium (K^+) were determined using flame photometer following the method previously described by **Oboh and Oladunmoye (2007)**.

Statistical analysis

The results obtained were analyzed using descriptive statistics (means and standard deviation). Analysis of variance, Pearson correlation analysis and Principal Component Analysis (correlation matrix were generated to assess the correlation) were carried out using Statistical Package of Social Sciences (SPSS version 20.0).

RESULTS AND DISCUSSION

Proximate composition

The proximate composition analysis including the protein, total sugars, reducing sugars, starch and amylose content was assessed for the 22 cultivars of pearl millet. Ca^{2+}), magnesium (Mg^{2+}), iron (Fe^{2+}) and zinc (Zn^{2+}) The obtained results are presented in Table 2 below.

Table 2 Proteins, sugars, starch, and amylose compositions in selected cultivars of pearl millets

Samples code	Parameters (Mean ± SD)				
	Proteins	**Total sugar**	**Reducing sugar**	**Starch**	**Amylose**
CA	3.41±1.55	178.64±7.88	16.62±4.30	50.51±7.89	49.67±2.86
CB	26.68±1.55	219.50±3.17	40.48±2.69	201.00±5.17	124.15±3.38
CC	12.33±2.32	303.45±4.50	33.81±4.30	263.86±1.38	211.52±5.17
CD	14.66±2.33	394.87±5.74	61.55±2.92	302.89±7.70	247.38±8.17
CE	26.68±1.55	429.91±2.30	144.15±1.46	196.11±8.30	130.85±3.82
CF	18.54±0.78	514.78±1.50	41.69±5.73	510.63±12.78	375.71±19.84
CG	45.69±3.89	579.91±2.63	63.90±1.43	452.66±5.67	412.90±3.58
CH	15.82±3.10	421.00±2.57	173.47±7.02	101.16±8.47	65.51±0.156
CI	8.07±1.55	377.05±10.72	47.66±1.46	372.84±6.05	282.01±10.14
CJ	17.00±2.33	594.62±5.36	77.63±2.92	507.59±9.81	492.73±13.66
CK	1.86±1.55	195.58±2.57	59.79±1.403	416.58±11.44	392.60±17.91
CL	10.78±2.32	337.98±3.75	174.22±12.89	163.67±9.05	99.42±6.72
CM	43.75±1.55	413.24±1.88	57.45±2.86	445.15±22.77	429.17±10.19
CN	9.62±3.10	495.64±6.76	33.81±4.30	299.40±0.97	274.31±5.57
CO	66.63±0.78	605.77±2.94	40.14±4.21	76.07±2.50	39.78±2.08
CP	15.82±1.55	652.54±2.25	46.00±2.86	146.13±9.93	139.03±3.38
CQ	20.487±1.55	580.85±2.25	57.45±2.86	383.68±6.50	350.00±9.02
CR	7.29±1.55	488.28±4.78	78.74±2.81	570.07±24.76	479.56±14.21
CS	65.08±0.77	465.85±3.309	119.44±2.81	515.295±11.07	491.40±-15.79
CT	93.40±1.55	359.05±3.06	85.67±4.38	478.35±6.00	342.78±12.10
CU	8.84±1.55	392.41±3.00	129.09±2.86	443.90±1.65	347.67±5.094
CV	32.11±3.10	604.77±4.21	79.82±4.38	560.55±7.81	390.44±25.734

The analysis of this table reveals that the protein contents vary from 1.86 mg/g (CK) to 93.4 mg/g (CT). This result shows that some of varieties have very low protein content. Among the 22 studied cultivars, six have a protein content less than 10 mg/g. However, the protein content obtained in this study is within the range of values reported in a study conducted in South Eastern USA (**Yadav et *al*., 2014**). These samples were found in both departments. Several studies showed that millet is a cereal relatively poor in protein (**Dykes and Rooney, 2007; Vanisha et *al*., 2011; Shweta, 2015)**. The total sugar content varied from 178.64 mg/g (CA) to 652.54 (CP) mg/g while the reducing sugar content varied from 16.62 mg/g (CA) to 174.22 mg/g (CL). Among the nutritional benefits, the hypoglycemic property made millets particularly popular for their use in the management of type II diabetes. This hypoglycemic characteristic could be attributed to the presence of polyphenols, soluble fiber, and low level of reducing sugars. Consistent with this, we found low levels of sugars in the millet cultivars under study. Similar finding was reported by **Taylor et *al*.** (**2006**). For the starch content, its values vary from 50.51 mg/g (CA) to 570.07 mg/g (CR). However, the highest value obtained for amylose content was 491.40 mg/g (CS). Starch contents were significantly correlated with amylose levels ($p < 0.001$). The presence of a large amount of starch in millet could decrease its digestibility. Indeed, **Rooney** and **Pflugfeder (1986**) showed that digestibility of starch is inversely proportional to amylose and amylopectin contents. Similar observation has been reported in previous studies (**Laurent, 1988; Michalet-Dorea et Sauvant, 1989**) of others cereals such as maize, sorghum, wheat, barley. However, the lower the proportion of amylose, the more gelatinization and vice versa. More the starch resist to gelatinization, more it was converted by alpha-amylases to glucose, which tends to raise the glycemic index **(Lopez-Rubio et *al*., 2009; Zhu et *al*., 2011).**

Nevertheless by the fermentation, hydrolysis of millet carbohydrates not only increases digestibility but also its nutritional quality. This justifies its use in some countries to supplement the diets of young children (**Songré-Ouattara et *al*., 2008**). This quality improvement is the result of a cascade enzymatic reactions performed by the fermentation flora and mainly lactic acid bacteria (**Songré-Ouattara et *al*., 2009)**.

Significant differences were observed in the proximate composition of millet samples under study. These differences were very highly significant for protein and sugar contents. It was noted that the samples collected from Borgou-Alibori region presented a best nutritional value than the samples collected from the region of Atacora-Donga. Similar findings have been reported in sorghum and millet (**Almeida-Dominguez et *al*., 1991**). These changes in the nutritional composition of the grains were found to be associated with both genetic and environmental factors (temperature, pluviometry, light intensity, physico-chemical characteristics of soil, etc.)

Mineral composition

The main minerals sought in pearl millet samples were Ca^{2+}, Mg^{2+}, K^{+}, Na^{+}, Fe^{2+} and Zn^{2+}. In addition to these inorganic elements, the dry matter and ash were measured and the results are presented in Table 3.

Table 3 Micronutrient composition of flour obtained from selected cultivar of pearl millet

Samples code	Parameters (mg/kg)							
	% DM	Ash	Ca^{2+}	Mg^{2+}	K^{+}	Na^{+}	Fe^{2+}	Zn^{2+}
CA	87.87	1.66	547.64	340.27	4401	196.19	36.07	481.03
CB	88.26	1.73	344.42	2775.18	3492	84.02	127.01	164.38
CC	88.01	1.54	424.36	2263.10	3824	240.47	70.92	214.14
CD	87.52	1.21	391.01	2081.72	3087	101.65	32.84	809.38
CE	88.72	2.9	94.02	1697.08	4128	78.04	1670.71	483.83
CF	88.31	1.36	187.50	2675.23	3648	85.58	37.69	269.53
CG	93.4	1.45	231.66	1588.41	3457	92.49	115.63	148.64
CH	87.98	1.60	75.61	1829.86	3920	105.06	63.13	313.79
CI	88.31	2.72	47.47	1646.84	3041	186.06	919.68	363.99
CJ	88.84	1.55	31.77	1566.87	3341	78.28	148.36	333.66
CK	87.37	2.55	88.56	1330.55	3425	106.28	248.89	547.97
CL	88.12	2.39	204.92	2689.41	3409	88.47	2766.31	528.07
CM	87.88	1.62	47.29	1544.98	3868	89.38	78.42	43.34
CN	88.57	1.36	219.60	2382.03	3319	68.31	37.25	56.86
CO	89.05	1.58	77.97	2264.32	3226	67.74	132.16	187.13
CP	88.21	1.45	676.69	2274.43	3022	58.37	39.47	233.08
CQ	88.84	2.12	500	2126.66	3352	114.21	103.97	200.75
CR	88.38	1.09	377.95	2772.51	3557	233.99	156.69	155.51
CS	89.35	1.56	576	1829.52	3663	132.28	56	204
CT	88.72	1.76	728.71	2482.29	4050	134.11	51.48	73.26
CU	87.71	1.53	468.29	4769.17	4082	179.95	13.85	261.46
CV	88.39	1.20	339.44	4415.27	3457	121.25	318.61	246.86

DM = Dry Matter; Ca^{2+} = Calcium; Mg^{2+} = Magnesium; K^{+} = Potassium; Na^{+} = Sodium; Fe^{2+} = Iron; Zn^{2+} = Zinc.

As shown in Table 3 above, the studied cultivars of pearl millet are rich in minerals and contain more minerals than corn and sorghum **(Almeida-Dominguez et *al*., 1993, 1991; N'guessan et *al*., 2014**). An analysis of this table reveals that the Ca^{2+} content in the analyzed samples varied between 31.77 mg/kg (CJ) and 728.71 mg/kg (CT). The levels of Mg^{2+} and Na^{+} ranged from 340.27 mg/kg (CA) to 4769.9 mg/kg (CU), and 58.37 mg/kg (CP) to 240.47 mg/kg (CC), respectively. For Fe^{2+} and Zn^{2+} the levels ranged from 13.85 mg/kg (CU) to 2766.31 mg/kg (CL), and 43.34 mg/kg (CM) to 809.38 mg/kg (CD), respectively. Indeed millet cultivated in Benin is an important source of Fe^{2+}, K^{+}, Mg^{2+} and Ca^{2+}. Note that for Ca^{2+} and Mg^{2+} the highest levels were obtained in samples collected from the region of Atacora-Donga. On the other hand, the highest levels of K^{+}, Na^{+}, Fe^{2+} and Zn^{2} were recorded in samples collected from the Borgou-Alibori region. No significant differences were observed for dry matter, ash and K^{+}, unlike all other minerals analyzed. Nevertheless, **Mouquet-Rivier et *al*. (2008**) reported lower content of iron and zinc for millet produced in Burkina Faso. Apart from all other minerals, it was noted that this cereal contains a very low content of Ca^{2+}. According to Recommended Dietary Allowance (RDA), this cereal cannot cover alone needs of Ca^{2+} for young children (which between 1,000 and 2,500 mg for children aged ≤ 8 years). Flour millet is also used in the feeding of young children in Benin. In Nigeria, **Akeredolu et *al*. (2005**) reported that this cereal can be used in dietary supplement to promote growth of children because of its nutrient content.

Correlation among nutritional parameters

The pearl millet and sorghum have the advantage of serving in both the nutrition of young children and adult ration where the antioxidants are very sought (**Obizoba and Atii, 1994; Ragaee et *al*., 2006)**. This characteristic depends on the mineral and nutritional composition. In this section, the correlations between variables were analyzed according to Pearson method. The table showed below presents the correlations between determined parameters (Table 4).

Table 4 Pearson correlation matrices between the physicochemical and nutritional parameters of peal millet collected in Benin

Parameters	DM	Ash	Ca^{2+}	Mg^{2+}	K^{+}	Na^{+}	Fe^{2+}	Zn^{2+}	Protein	Total sugars	Reducing sugars	Starch
Ash	-0.114											
Ca^{2+}	-0.030	-0.333										
Mg^{2+}	-0.144	-0.324	0.211									
K^{+}	-0.112	0.049	0.187	-0.063								
Na^{+}	-0.190	-0.083	0.313	0.080	0.362*							
Fe^{2+}	-0.054	0.655***	-0.302	0.007	-0.036	-0.134						
Zn^{2+}	-0.345	0.343	-0.154	-0.230	-0.098	-0.018	0.395*					
Protein	0.411*	-0.123	0.236	0.024	0.128	-0.234	-0.163	-0.460*				
Total sugar	0.438*	-0.369*	-0.036	0.256	-0.453*	-0.388*	-0.157	-0.353	0.243			
Reducing sugar	-0.029	-0.131	-0.131	0.247	0.268	-0.097	0.554**	0.213	0.056	0.005		
Starch	0.201	0.047	0.047	0.333	-0.073	0.192	-0.253	-0.288	0.181	0.267	-0.022	
Amylose	0.242	0.019	0.019	0.158	-0.104	0.149	-0.312	-0.287	0.144	0.278	-0.065	0.963***

DM: dry matter; Ca^{2+}: calcium; Mg^{2+}: magnesium; K^{+}: potassium; Na^{+}: sodium; Zn^{2+}: zinc; Fe^{2+}: Iron; * indicate a significant correlation ($p < 0.05$); ** indicate a highly significant correlation ($p < 0.01$); *** indicate a very highly significant correlation ($p < 0.001$)

It is clear from this analysis that the low ash content induces the high protein content. For sugar content a significant correlation was also observed with the ash ($p < 0.05$). This observation is in agreement with an earlier study on grain of sorghum **(Subramanian and Jambunathan, 1982)**. However, some authors have observed an inverse association between the protein content and starch content of grains. This relationship had already been demonstrated in sorghum by a group of researchers **(Chandrashekar and Kirleis, 1988)**. The previous authors showed that the presence of proteins affects the starch gelatinization. The gelatinization was also influenced by the amylose content. Our study showed highly significant correlation ($p < 0.001$) between amylose and starch. The study conducted on rice showed that, higher is the proportion of amylose, the lower is the gelatinization and vice versa (**Chung et *al*., 2011**). In another study, it was demonstrated that the differences between the physicochemical and nutritional parameters of starch are also a function of the structural characteristics of cultivars (**Chávez-Murillo et *al*., 2012**). In addition to starch compositions, other parameters including physicochemical compositions are also important to determine the nutritional value of a given cereal. Yet for many product it has been shown that the ash content is often correlated with carbon and minerals contents (**Monti et *al*., 2008**).

Among the minerals only iron was significantly correlated with ash ($p < 0.001$). Indeed all monovalent ions (K^{+} and Na^{+}) and divalent ions (Fe^{2+}, Ca^{2+} and Zn^{2+}) analyzed in millet are negatively correlated with total sugar content (and significantly for Na^{+} and K^{+} that is to say, $p < 0.05$). Conversely, among the divalent ions, only Mg^{2+} was positively correlated with the total sugar content. Likewise Fe^{2+} was significantly correlated with reducing sugars ($p < 0.01$) and significant correlated with Zn^{2+} to protein ($p < 0.05$). The salts are known for their influence on the rheological behavior of simple sugars. In a study performed in Sudan on millet, it has been shown that fermentation could improve the millet' protein digestibility and therefore its nutritional quality (**Hag et *al*., 2002**). Note that in addition to iron, ash content was significantly correlated with total sugar content.

Correlation between cultivars and nutritional parameters according and Principal Components Analysis.

The analysis of the dispersion of the different variables followed by the screening of all samples following the axes 1 and 2 (Figure 1 A and B) shows that millet samples can be divided into four distinct groups. We have chosen descriptors of iron-rich millets (group G1), carbohydrate-rich millets (group G2), and two less nutritious millets (groups G3 and G4).

The iron-rich group (G1) was composed of four cultivars such as CL, CE, CH and CI. In addition to iron, this group is characterized by cultivars with high levels in ash, zinc and reducing sugars. The cultivars of group G1 could be recommended for preventing anemia because of their high iron content. Also, the body requires iron for the synthesis of oxygen transport proteins, in particular hemoglobin and myoglobin, and for the formation of enzymes involved in electron transfer (**McDowell, 2003**). For the zinc, it plays the important roles (structural and functional) in many macromolecules and is required for enzymatic reactions. Zinc ions participate in all aspects of intermediary metabolism, transmission, and regulation of the expression of genetic information, storage, synthesis, and action of peptide hormones and structural maintenance of chromatin and biomembranes (**Meunier et *al*., 2005**).

The "carbohydrates" group (G2 group) is characterized by the pearl millet cultivars (CS, CO, CG, CJ, CP, CN, CQ, CF, CV, CS and CM) containing a high content of starch, amylose, total sugars, protein and dry matter. The cultivars of this group could be used in diet needing the high content in protein and sugar sources specially the child's and adolescents. They are not recommended for diabetics and older people, but they can be important in starch industry. The other cultivars are less nutritious and are classified into G3 and G4 groups.

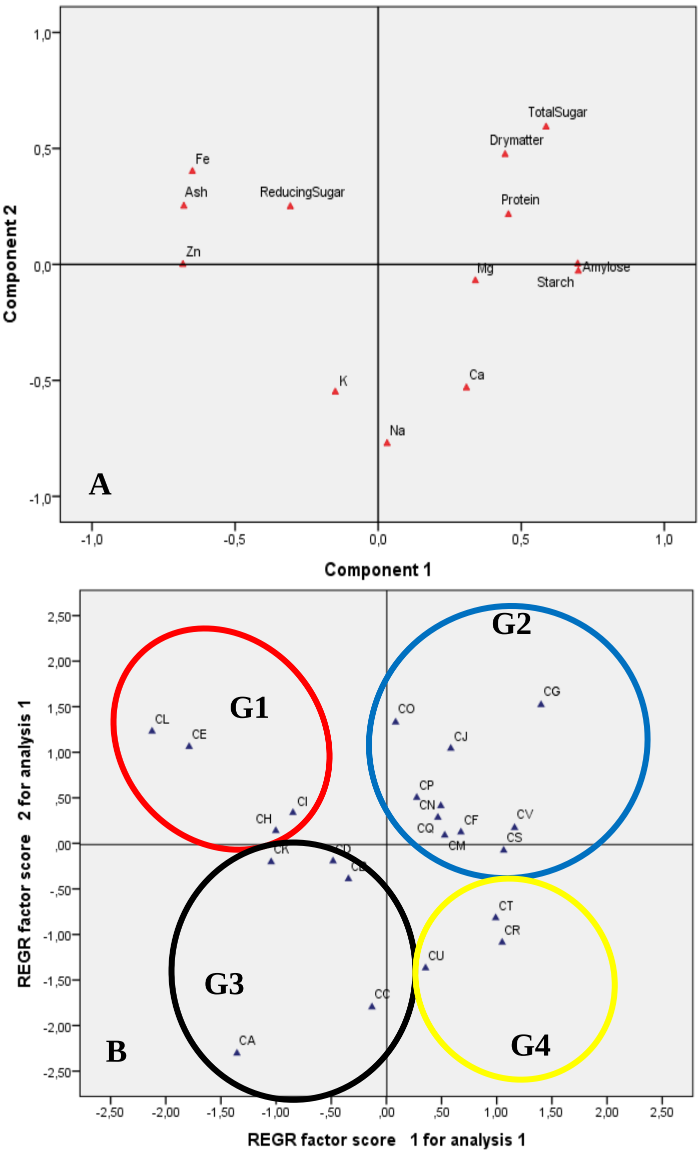

Figure 1 Factors dispersion plot according to the Principal Component Analysis (PCA) method (**A**); Projection of the pearl millet samples on the first and second component axes (**B**),

CONCLUSION

We show in this study that Benin has a diversity of cultivated pearl millets. The assessment of the nutritional value of 22 varieties of millets revealed that concentrations of major and minor nutrients like carbohydrate, proteins, sugars as well as minerals, varied widely. In general, we found no "*all-in-one*" variety capable of providing all potential health benefits attributed to pearl millets. In contrast, millet varieties under study were found to possess' relatively low levels of proteins and sugars, but high levels of starch, amylose, Mg^{2+}, Zn^{2+}, Fe^{2+}. Variations in the levels of those nutrients were dependent on both millet variety and site of production. Nutrient-rich millets could be used to improve nutritive value of other local varieties produced in Benin. Finally, this study supports evidence that millet could be recommended for preventing malnutrition or dietary deficiency in populations using millet as the basic staple food, particularly children and rural farming communities. Considering the high levels of starch observed here, further studies investigating all three types of starch, and thus millet digestibility, are needed.

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