J. Food Chem. Nutr. 06 (01) 2018. 13-20 DOI: 10.33687/jfcn.006.01.2343

Available Online at ESci Journals
Journal of Food Chemistry and Nutrition
ISSN: 2307-4124 (Online), 2308-7943 (Print)
http://www.escijournals.net/JFCN

GENOTYPIC VARIATION OF MINERAL ELEMENTS AND PHYTATE LEVELS OF THIRTY COWPEAS (*VIGNA UNGUICULATA L.* WALP.) VARIETIES CULTIVATED IN BURKINA FASO

[a]Pierre A.E.D. Sombié*, [b]Ibrahim Ouedraogo, [a]Jean Baptiste D.L.S Tignegré, [b]Adama Hilou, [a]Tinga J. Ouedraogo, [b]Martin Kiendrébéogo

[a] National Center of Scientific and Technological Research, Institute of Environment and Agricultural Research, Crop Production Department, P.O Box 476 Ouagadougou, Burkina Faso.
[b] Laboratory of Biochemistry and Chemistry Applied (LABIOCA), University of Ouaga I Professor Joseph Ki-Zerbo, P.O Box 848 Ouagadougou, Burkina Faso.

A B S T R A C T

Cowpea is consumed as a staple food in many developing countries. The present study was undertaken to determine the variation in mineral elements and phytate concentrations in 30 cowpeas seeds varieties consumed in Burkina Faso. The composition of the thirty cowpeas seeds in total mineral varies from 5.08 % ± 0.00 to 3.55 % ± 0.08. The genotype CR06-07 showed the high content of total mineral (ashes) and the genotype Kondesyoungo local, the low content of ashes. IT81D-994 showed the high content of iron (7.07 ± 0.057 mg/100g of seeds dw), zinc (4.42 ± 0.012 mg/100 g of seeds dw), magnesium (239.80 ± 1.192 mg/100 g of seeds dw), calcium (123.39 ± 2.31 mg /100 g of seeds dw) and potassium (1201.97 ± 25.66 mg/100 g of seeds dw). Na and Se levels in the seeds showed about 4.5-fold and 7.6-fold variations between the cowpeas varieties. The genotype komcallé showed the high content of sodium (5.45 ± 0.20 mg/100 g of seeds dw) and the genotype KVx 414-22-2 had the high content of selenium (0.006 ± 0.0002 mg/100 g of seeds dw). The phytate content of the cowpeas genotypes varied from 555.61 ± 7.48 for TVU 14676 to 13.50 ± 1.14 mg/100 g of seeds dw for KVx 30-309-6G. The [Phy]/[Fe], [Phy]/[Zn], [Phy]/[Ca] and [Phy] x [Ca]/[Zn] ratios showed that the phytate content might compromise the Fe, Zn and Ca bioavailability in some cowpeas varieties. This study indicates that the cowpeas varieties might be considered as mineral source suitable for animal and human consumption.

Keywords: Cowpea (*Vigna unguiculata*), Mineral content, Phytate content, Mineral bioavailability, Burkina Faso.

INTRODUCTION

Micronutrient malnutrition, the so-called hidden hunger now afflicts over 40 % of the world's population, especially resource-poor women, infants and children in the developing world (Pfeiffer & McClafferty, 2007; Welch & Graham, 2002). The deficiency of minerals in the body can result in an abundant incidence of common disorders and disease symptoms (Gharibzahedi & Jafari, 2017). Minerals have key roles in our body to do necessary functions from building strong bones to transmitting nerve impulses for healthy and long-life (Gharibzahedi & Jafari, 2017). Minerals are fundamentally metals and other inorganic compounds present in all body tissues and fluids and their presence is necessary for the maintenance of certain physicochemical processes which are essential to life (Gupta & Gupta, 2014). Humans require at least 28 mineral elements for normal nutrition that are known to play key role in maintaining human health (Gupta & Gupta, 2014). An appropriate intake of micromineral is necessary for the human organism to avoid a wide range of associated health problems (Santos & Boiteux, 2013). Mineral nutrients can be separated into major secondary and micro or trace minerals. Major: P and K; secondary: calcium (Ca), magnesium (Mg) and sulfur (S); and micro or trace or rare: boron (B), chlorine (Cl), chromium (Cr), fluoride (Fl), iodine (I), iron (Fe), manganese (Mn), molybdenum (Mo), nickel (Ni), selenium (Se), sodium (Na), vanadium (V) and zinc

* Corresponding Author:
Tel: 0022671355445
Email ID: ericsombie@yahoo.fr

(Zn)(Gupta & Gupta, 2014). In sub-Saharan Africa many persons suffer from mineral deficiencies due to consumption of monotonous cereal based diets (Kruger *et al*., 2015). Legumes and cereals foods, which form the base of diets for most African communities contain phytic acid. Phytic acid (myo-inositol 1, 2, 3, 4, 5, 6,-hexakis dihydrogen phosphate), a compound that is only present in plant foods has been found to reduce the bioavailability of several minerals by forming insoluble complex with the divalent minerals in foods (Onabanjo & Oguntona, 2003). It has been linked to mineral deficiency because of its affinity with minerals, mainly Fe, Zn, Ca and Mg (Ficco *et al*., 2009). The absolute effects of phytate on mineral bioavailability have long been known to depend on the relative levels of both minerals and phytate in foods (Onabanjo & Oguntona, 2003).

Cowpea beans (*Vigna unguiculata* (L.) Walp.) are one of the most important staple foods for people in west Africa, Asia and South America. Their seeds are known to be an excellent source of protein; vitamins, minerals and soluble and insoluble dietary fiber (Zia-Ul-Haq *et al*., 2013). It is an excellent source of minerals particularly in iron and zinc. Cowpea is known as 'beenga'in mooré, Burkina Faso principal language. The development of improved cowpeas cultivars that contain higher mineral content in famer's preference is expected to have important implications toward assuring food security. The determination of existence and sufficient genetic variation of some mineral elements in cowpeas will help to improve further the nutritional quality of this crop by both conventional breeding and transgenic approaches. The purpose of this study was to determine genotypic variation of selected mineral elements and phytate levels of thirty cowpeas varieties in Burkina Faso. The [phytate]/ [Fe], [phytate]/ [Zn], [phytate]/ [Ca] and [calcium] x [phytate]/ [zinc] ratios were also calculated as an index for predicting the potential mineral bioavailability in cowpeas seeds.

MATERIALS AND METHODS

Plant Material: Cowpeas (*Vigna unguiculata*) seeds of thirty (30) varieties were obtained from the genetic and biotechnology laboratory germplasm, Department of Crop Production, Institute of Environment and Agricultural Research Institute, Burkina Faso.

Moisture and ash content: The moisture was determined by drying in an electric oven at 110 °C until a constant weight was obtained. Moisture content was then calculated as per cent water loss. The ash content was determined after calcination in a muffle furnace at 550°C.

Mineral content determination: The minerals that were analyzed include iron, zinc, selenium, sodium, potassium, magnesium and calcium. Identification and quantification of minerals were performed using Inductively Coupled Plasma (ICP) optical emission spectroscopy at a sub-contracted laboratory.

Phytate analysis: Phytate content was determined in the food samples according to the method of Wheeler & Ferrel (1971). This method involves extracting phytate with 3% trichloroacetic acid and precipitating it as ferric phytate. The ferric phytate was then converted to ferric hydroxide ($Fe(OH)_3$ precipitate and soluble sodium phytate by adding sodium hydroxide and boiling. The precipitate was then dissolved in diluted acid and the iron content determined colorimetrically. A reagent blank was run with each set of samples. $Fe(NO_3)_3$ standards were prepared, and absorbance read with the spectrophotometer. This was then used to prepare a standard curve from which the iron concentrations were obtained. The phytate content was then calculated from the iron concentration by assuming a constant Fe:P molecular ratio of 4:6 in the precipitate. The phytic acid was estimated by multiplying the amount of phytate phosphorus by the factor 3.55 based on the empirical formula $C_6P_6O_{24}H_{18}$. Values reported are the means of six replicates.

Molar ratios of dietary phytate to iron, zinc, calcium and phytate x calcium: zinc of cowpeas varieties: To predict the inhibiting effect of phytate to iron, zinc and calcium bioavailability from cowpea, the molar ratios of [phytate]/[Fe], [phytate]/[Zn], [phytate]/[Ca] and [calcium] x [phytate]/ [zinc] were calculated as an index for the potential mineral bioavailability. Critical values above 1 for [phytate]/ [Fe], 15 for [phytate]/ [Zn] and 200 for [calcium] x [phytate]/ [zinc] were used as reference for predicting poor bioavailability. The [calcium] x [phytate]/ [zinc] molar ratio was expressed as millimoles per 100 g of seeds dw (Lazarte *et al*., 2015).

Statistical analysis: The data are presented as mean ± SD for triplicate analysis. The results were subjected to one-way analysis of variation ANOVA with Turkey's Least Significant Difference test. $P < 0.05$ was considered significant. The Pearson Correlation test for correlation analysis was used. The statistical analysis was performed using XLSTAT version 7.5.2 (Addinsoft, FRANCE).

RESULTS AND DISCUSSION

Moisture and ash content: The percentage of moisture and total mineral in thirty cowpeas genotypes seeds consumed in Burkina Faso are presented in Table 1. The composition of the cowpeas seeds in moisture varies from 7.12 % ± 0.05 to 8.64 % ± 0.00 respectively for the KV x 402-5-2 and Labagela local genotypes. Labagela local genotype contain the significant high content of moisture among the genotypes except for KVx745-11P, Tiligré, Mougné, KVx 396-4-5-2D, IT 93K-693-2, Niizwé, CR06-07 and Gourgou genotypes. The moisture content varies slightly from variety to another. The moisture content of all the cowpeas varieties are desirable compared with 8 to 9 % recommended for long-term storage. Moisture content of food samples is the main determinant of food spoilage. High moisture contents in food products facilitate the activities of microorganisms; reduce the nutritional quality and shelf life of the food products (Ijarotimi *et al*., 2015).

CR06-07 genotype showed the high significant content of total mineral (ash) and the genotype Kondesyoungo local, the low content of total mineral. The content of total mineral varies widely from 3.55 % ± 0.08 to 5.08 % ± 0.00 between the thirty varieties of cowpeas. The total mineral value of CR06-07 genotype was higher than those of White coat small cowpea (3.61 % ± 0.0) reported by Olaleke et al.(2006). Generally, high ash content is an indication that the seeds contain abundant mineral content (Ogunyinka *et al*., 2017).

Mineral elements content: Iron, zinc, selenium, calcium, magnesium, sodium and potassium contents in thirty cowpeas genotypes seeds consumed in Burkina Faso are presented in Table 1. The mineral concentrations in cowpeas seeds showed wide genotypic variation. The results obtained prove that the potassium, magnesium and calcium were the predominant mineral elements analyzed in all the varieties of cowpeas seeds. These elements are essential in numerous biological functions and are very important for health.

The genotype of cowpea IT 81D-994 showed the significant ($p < 0.05$) high content of iron (7.07 ± 0.057 mg/100g of seeds dw), zinc (4.42 ± 0.012 mg/100 g of seeds dw), magnesium (239.8 ± 1.192 mg/100 g of seeds dw) and calcium (123.39 ± 2.31 mg /100 g). The genotype of cowpea IT 81D-994 had also the high content of potassium (1201.97 ± 25.66 mg/100 g of seeds dw) but no significantly different with those of CR 06-07 (1167.29 mg/100 g of seeds dw). Over 2-fold variation in seeds Fe and in seeds Zn concentration between the cowpeas varieties were observed. Ca and Mg levels in the seeds showed about 2-fold variation between the cowpeas varieties.

Iron takes part in production of hemoglobin and myoglobin, oxygenation of red blood cells, essential for many enzymes, important for growth and zinc is an antioxidant involved in antioxidant defense systems, constituent of insulin and many vital enzymes (more than 300 enzymes), required for protein synthesis including transcription factors and collagen formation and promoting a healthy immune system (Gupta & Gupta, 2014; Souza *et al*., 2014; Welch & Graham, 2002;). Zinc status in plants is directly correlated with plant growth, crop yield, and product nutritional quality (Souza *et al*., 2014). Calcium in conjunction with magnesium, phosphorus and protein are involved in bone formation, magnesium helps in the maintenance of the electrical potential of nerves and potassium is very essential in blood clotting and muscle contraction (Obi & Okoye, 2017). The genotype KV x 414-22-2 had the high content of selenium. The Se concentration in seeds varied from 0.0058 ± 0.00016 to 0.00076 ± 0.00001 mg/100 g of seeds dw) showing 7.6-fold difference between the cowpeas varieties. Selenium, a vital antioxidant is an essential micronutrient for humans and animals by principally inhibiting the oxidation of lipids and as the key component of more than 25 mammalian selenoenzymes or selenoproteins with important biological functions (Gupta & Gupta, 2014; Souza *et al*., 2014). The genotypes komcallé and Niango local showed the high content of sodium respectively of 5.45 ± 0.202 and 5.41 ± 0.00 mg/100 g of seeds dw. Na level in the seeds showed about 4.5-fold variation between the cowpeas varieties. Sodium is necessary for maintaining proper water balance and blood pH, needed for stomach, nerve and muscle function (Gupta & Gupta, 2014). Furthermore, excessive intake of sodium is associated with high blood pressure or hypertension, which is a major risk factor for cardiovascular diseases (Kamis *et al*., 2015). The Na/K ratio of all the genotypes is inferior to 1. Na/K ratio less than one is recommended (Olaleke *et al*., 2006). These results indicate that the cowpeas varieties studied might be considered as mineral source suitable for animal and human consumption, especially for people who require a low sodium diet. Furthermore, micronutrient-dense seeds can increase crop yields when sowed to micronutrient-poor soils (Welch & Graham, 2002). Pearson correlation matrix between all these mineral elements was performed and presented in Table 3.

Table 1. Mineral elements content of thirty cowpeas genotypes.

Cowpea genotype	Percentage (%)		mg/100 g of seeds dry weight							Ratio
	Moisture	Ashes	Fe	Zn	Se	Mg	Ca	Na	K	Na/K
58-57	8.21 ± 0.00 ^{a,b,c}	4.31 ± 0.00 ^{e,f}	4.29 ± 0.028 ^{d,e}	2.50 ± 0.008 ^{h}	0.00076 ± 0.0000 ^{m}	175.20 ± 3.99 c	89.13 ± 2.24 ^{b,c,d,e}	1.90 ± 0.05 ^{l,m}	953.27 ± 14.22 ^{c,d,e}	0.00201 ± 0.00002
CR06-07	8.36 ± 0.00 ^{a,b}	5.08 ± 0.00 ^{a}	3.71 ± 0.042 ^{i,j,k,l}	3.00 ± 0.027 ^{d}	0.00275 ± 0.00005 ^{f}	193.63 ± 1.21 b	94.06 ± 1.51 ^{b,c}	2.93 ± 0.02 ^{g,h,i}	1167.29 ± 1.73 ^{a}	0.00252 ± 0.00002
IT 81 D-994	8.22 ± 0.00 ^{a,b,c}	4.68 ± 0.00 ^{b}	7.07 ± 0.057 ^{a}	4.42 ± 0.012 ^{a}	0.00224 ± 0.00004 ^{h,i}	239.80 ± 1.19 a	123.39 ± 2.31 ^{a}	3.05 ± 0.02 ^{f,g}	1201.97 ± 25.66 ^{a}	0.00252 ± 0.00004
IT 93 K-693-2	8.41 ± 0.00 a	4.54 ± 0.00 ^{d}	4.04 ± 0.024 ^{f,g,h}	2.42 ± 0.009 ^{h,i}	0.00194 ± 0.00003 ^{k}	152.36 ± 8.37 e,f,g,h,i	70.17 ± 0.05 ^{j,k,l}	2.67 ± 0.07 ^{h,i,j}	1013.17 ± 7.11 ^{b}	0.00266 ± 0.00005
IT 97 K-489-35	7.38 ± 0.05 ^{e,f}	3.89 ± 0.02 ^{n,o}	3.57 ±0.107 ^{j,k,l}	2.30± 0.027 ^{i,j}	0.00119 ± 0.00002 ^{l}	138.20 ± 5.78 ^{i,j,k,l}	68.11 ± 2.59 ^{k,l}	4.15 ± 0.12 ^{b}	832.80 ± 9.58 ^{k,l}	0.00504 ± 0.00010
IT 97 K-573-2 (Yiisyandé)	8.32 ± 0.00 ^{a,b}	4.64 ± 0.00 ^{b,c}	3.79 ± 0.004 ^{i,j}	2.69 ± 0.018 ^{f,g}	0.00233 ± 0.00003 ^{g,h}	166.89 ± 5.58 ^{c,d,e}	76.21 ± 1.68 ^{h,i,j}	3.98 ± 0.33 ^{b,c}	994.13 ± 12.57 ^{b,c}	0.00415 ± 0.00028
IT 98K-205-8 (Niizwé)	8.39 ± 0.00 ^{a,b}	4.58 ± 0.00 ^{c,d}	5.07 ± 0.061 ^{b}	2.91 ±0.042 ^{d,e}	0.00315 ± 0.00005 ^{e}	148.28 ± 0.22 ^{g,h,i,j}	92.24 ± 2.59 ^{b,c,d}	2.41 ± 0.15 ^{j,k}	952.31 ± 5.97 ^{c,d,e}	0.00261 ± 0.00015
Kondèsyoungo local	7.81 ± 0.22 ^{b,c,d,e}	3.55 ± 0.08 ^{r}	4.74±0.141 ^{c}	3.16 ±0.096 ^{c}	0.00482 ±0.0001 ^{b}	121.16 ± 5.43 ^{m}	68.23 ± 2.00 ^{k,l}	3.04 ± 0.20 ^{f,g,h}	719.08 ± 23.84 ^{m}	0.00431 ± 0.00018
KVx 30-309-6G	7.19 ± 0.01 ^{f}	3.92 ± 0.01 ^{m,n}	3.30 ± 0.016 ^{m,n}	2.13 ± 0.006 ^{k,l}	0.00294 ± 0.00003 ^{e,f}	129.79 ± 7.21 ^{k,l,m}	63.48 ± 0.69 ^{l,m}	3.60 ± 0.17 ^{d,e}	887.48 ± 10.74 ^{f,g,h,i,j}	0.00412 ± 0.00014
KVx 396-4-5-2D	8.43 ± 0.00 ^{a}	4.01 ± 0.00 ^{j,k,l}	2.94 ± 0.087 ^{p}	1.81 ± 0.001 ^{p}	0.00284 ± 0.00003 ^{f}	135.96 ± 1.68 ^{j,k,l}	83.68 ± 0.96 ^{e,f,g}	3.60 ± 0.11 ^{d,e}	873.59 ± 7.51 ^{g,h,i,j,k}	0.00416 ± 0.00009
KVx 402-5-2	7.12 ± 0.05 ^{f}	3.70 ± 0.12 ^{q}	3.50 ± 0.135 ^{l,m}	2.09 ±0.081 ^{l,m}	0.00208 ± 0.00009 ^{i,j,k}	141.86 ± 6.05 ^{i,j,k}	85.15 ± 4.60 ^{e,f,g}	1.81 ± 0.08 ^{m}	906.10 ± 34.93 ^{e,f,g,h,i}	0.00202 ± 0.00003
KVx 414-22-2	8.33 ± 0.23 ^{a,b}	4.24 ± 0.1 ^{f,g}	5.02 ±0.123 ^{b}	3.47 ± 0.083 ^{b}	0.00584± 0.00016 ^{a}	175.37 ± 5.43 ^{c}	85.71 ± 2.49 ^{d,e,f}	3.34 ± 0.11 ^{e,f}	993.09 ± 23.05 ^{b,c}	0.00340 ± 0.00007
KVx 421-2J	7.60 ± 0.01 ^{e,f}	4.11 ± 0.08 ^{h,i}	3.79 ± 0.104 ^{i,j}	1.88 ± 0.044 ^{o,p}	0.00222 ± 0.00005 ^{h,i,j}	136.77 ± 3.17 ^{j,k,l}	87.09 ± 2.03 ^{d,e,f}	2.14 ± 0.06 ^{k,l,m}	844.79 ± 21.83 ^{j,k,l}	0.00254 ± 0.00001
KVx 442-3-25-SH (Komcallé)	7.28 ± 0.04 ^{e,f}	3.99 ± 0.03 ^{k,l,m}	3.78 ± 0.124 ^{i,j,k}	2.38 ±0.032 ^{h,i,j}	0.00291 ± 0.00005 ^{f}	137.76 ± 2.75 ^{i,j,k,l}	73.40 ± 1.01 ^{i,j,k}	5.45 ± 0.20 ^{a}	866.88 ± 10.69 ^{h,i,j,k}	0.00638 ± 0.00018
KVx 61-1	7.21 ± 0.03 ^{f}	3.86 ± 0.00 ^{n,o}	3.23 ± 0.039 ^{n,o}	2.34 ± 0.025 ^{i,j}	0.00235 ± 0.00006 ^{g,h}	137.02 ± 1.16 ^{j,k,l}	58.14 ± 1.69 ^{m}	3.74 ± 0.19 ^{c,d}	886.24 ± 10.96 ^{f,g,h,i,j}	0.00431 ± 0.00016
KVx 65-114	7.53 ± 0.03 ^{e,f}	3.84 ± 0.00 ^{o,p}	2.94 ± 0.025 ^{p}	2.01 ± 0.011 ^{l,m,n}	0.00236 ± 0.00003 ^{g,h}	139.94 ± 2.66 ^{i,j,k,l}	74.55 ± 0.84 ^{i,j,k}	1.19 ± 0.03 ^{n}	854.40 ± 4.61 ^{j,k}	0.00141 ± 0.00003
KVx 745-11P	8.60 ± 0.89 ^{a}	4.36 ± 0.07 ^{e}	3.77 ± 0.044 ^{i,j,k}	3.38 ± 0.041 ^{b}	0.00192 ± 0.00002 ^{k}	166.48 ± 4.31 ^{c,d,e,f}	78.85 ± 2.14 ^{g,h,i}	3.32 ± 0.10 ^{e,f}	969.95 ± 8.40 ^{b,c,d}	0.00346 ± 0.00008
KVx 771-10G (Nafi)	7.66 ± 0.07 ^{c,d,e,f}	3.98 ± 0.03 ^{l,m}	2.82 ± 0.036 ^{p}	2.38 ± 0.032 ^{h,i}	0.00281 ± 0.00006 ^{f}	125.58 ± 1.12 ^{l,m}	73.74 ± 0.86 ^{i,j,k}	1.34 ± 0.05 ^{n}	882.38 ± 7.38 ^{g,h,i,j,k}	0.00154 ± 0.00005
KVx 775-33-2G (Tiligré)	8.52 ± 0.00 ^{a}	3.97 ± 0.00 ^{l,m}	2.88 ± 0.013 ^{p}	2.25 ± 0.031 ^{j,k}	0.00202 ± 0.00003 ^{j,k}	118.78 ± 4.27 ^{m}	88.95 ± 3.93 ^{b,c,d,e,f}	1.24 ± 0.00 ^{n}	861.59 ± 2.55 ^{i,j,k}	0.00144 ± 0.00000
KVx 780-1	7.83 ± 0.08 ^{b,c,d,e}	3.77 ± 0.04 ^{p,q}	3.01 ± 0.05 ^{o,p}	1.90 ± 0.026 ^{n,o,p}	0.00293 ± 0.00004 ^{f}	142.93 ± 3.65 ^{h,i,j,k}	72.04 ± 1.02 ^{j,k}	3.41 ± 0.10 ^{d,e,f}	834.88 ± 11.60 ^{k,l}	0.00414 ± 0.00010
KVx 780-3	7.28 ± 0.1 ^{e,f}	3.72 ± 0.06 ^{q}	2.97± 0.069 ^{p}	1.96 ± 0.043 ^{n,o}	0.00241 ± 0.00007 ^{g,h}	137.81 ± 9.02 ^{i,j,k,l}	87.73 ± 1.91 ^{c,d,e,f}	2.69 ± 0.17 ^{g,h,i,j}	876.34 ± 23.18 ^{g,h,i,j,k}	0.00313 ± 0.00014
KVx 780-4	7.62 ± 0.02 ^{d,e,f}	3.87 ± 0.08 ^{n,o}	2.99 ± 0.078 ^{p}	1.98 ± 0.054 ^{m,n,o}	0.00282 ± 0.00008 ^{f}	126.92 ± 4.19 ^{l,m}	82.28 ± 2.93 ^{f,g,h}	2.42 ± 0.07 ^{j,k}	846.47 ± 28.71 ^{j,k,l}	0.00284 ± 0.00003
KVx 780-6	8.18 ± 0.00 ^{a,b,c,d}	4.55 ± 0.00 ^{d}	3.23 ± 0.055 ^{n,o}	2.37 ± 0.018 ^{h,i,j}	0.00210 ± 0.00003 ^{i,j,k}	157.17 ± 1.89 ^{d,e,f,g,h}	86.67 ± 2.81 ^{d,e,f}	2.69 ± 0.06 ^{g,h,i,j}	991.58 ± 22.12 ^{b,c}	0.00272 ± 0.00000
KVx 780-9	8.26 ± 0.14 ^{a,b}	4.24 ± 0.05 ^{f}	3.53 ± 0.065 ^{l,m}	2.31 ± 0.039 ^{i,j}	0.00129 ± 0.00003 ^{l}	159.06 ± 3.43 ^{d,e,f,g}	94.87 ± 1.58 ^{b}	2.92 ± 0.06 ^{g,h,i}	921.46 ± 15.38 ^{d,e,f,g}	0.00319 ± 0.00002
Labagela local	8.64 ± 0.00 ^{a}	3.86 ± 0.00 ^{n,o}	4.13 ±0.014 ^{e,f}	2.68 ± 0.037 ^{f,g}	0.00415 ±0.00008 ^{d}	133.19 ± 1.93 ^{k,l,m}	57.06 ± 1.42 ^{m}	2.65 ± 0.02 ^{i,j}	801.53 ± 13.83 ^{l}	0.00329 ± 0.00003
Mougne	8.46 ± 0.00 ^{a}	4.70 ± 0.00 ^{b}	3.88 ± 0.124 ^{g,h,i}	2.65 ± 0.017 ^{g}	0.00221 ± 0.00004 ^{h,i,j}	152.20 ± 8.37 ^{f,g,h,i}	94.34 ± 1.10 ^{b,c}	2.59 ± 0.08 ^{i,j}	1004.82 ± 2.21 l ^{b}	0.00261 ± 0.00007
Moussa local	7.68 ± 0.15 ^{c,d,e,f}	4.06 ± 0.04 ^{i,j}	3.55 ± 0.54 ^{k,l}	2.32 ±0.038 ^{i,j}	0.00441 ±0.00011 ^{c}	149.95 ± 7.18 ^{g,h,i,j}	76.38 ± 1.95 ^{h,i,j}	2.20 ± 0.05 ^{k,l}	847.95 ± 7.64 ^{j,k,l}	0.00261 ± 0.00004
Niango local	8.21 ± 0.00 ^{a,b,c}	4.29 ± 0.00 ^{e,f}	3.84 ± 0.006 ^{h,i}	2.48 ± 0.025 ^{h}	0.00202 ± 0.00002 ^{j,k}	171.56 ± 0.51 ^{c,d}	95.10 ± 1.84 ^{b}	5.41 ± 0.00 ^{a}	918.46 ± 0.35 ^{e,f,g}	0.00589 ± 0.00000
TVU 14676	7.30 ± 0.01 ^{e,f}	4.12 ± 0.04 ^{h,i}	4.39 ± 0.069 ^{d}	2.79 ± 0.059 ^{e,f}	0.00250 ± 0.00005 ^{g}	156.66 ± 2.16 ^{e,f,g,h}	73.79 ± 2.12 ^{i,j,k}	1.98 ± 0.07 ^{l,m}	934.80 ± 12.13 ^{d,e,f}	0.00215 ± 0.00006
TZ-1 (Gourgou)	8.36 ± 0.00 ^{a,b}	4.16 ± 0.00 ^{g,h}	4.11± 0.026 ^{e,f,g}	2.85 ±0.019 ^{e}	0.00277 ± 0.00003 ^{f}	128.58 ± 0.97 ^{k,l,m}	83.28 ± 0.59 ^{e,f,g}	2.45 ± 0.06	914.13 ± 10.48 ^{e,f,g,h}	0.00270 ± 0.00004

Data were expressed as mean ± SE. Means with different superscript along the row differs significantly ($P < 0.05$).

Table 2. Phytate content and molar ratios of phytate to calcium, iron and zinc in thirty cowpea genotypes.

Cowpea genotype	Phytate (mg/100 g of seeds dw)	Molar ratio Phy : Fe	Molar ratio Phy : Zn	Molar ratio Phy: Ca	Molar ratio Phy*Ca: Zn
58-57	324.91 ± 5.64 [d]	6.43 ± 0.13	12.81 ± 0.26	0.22 ± 0.01	28.49 ± 1.02
CR06-07	172.75 ± 2.05 [g]	3.96 ± 0.05	5.66 ± 0.07	0.11 ± 0.00	13.29 ± 0.26
IT 81 D-994	117.03 ± 1.54 [i,j]	1.41 ± 0.00	2.62 ± 0.02	0.06 ± 0.00	8.08 ± 0.20
IT 93 K-693-2	57.96 ± 5.5 [n]	1.25 ± 0.11	2.43 ± 0.21	0.05 ± 0.00	4.25 ± 0.37
IT 97 K-489-35	82.93 ± 0.45 [l]	1.97 ± 0.06	3.55 ± 0.05	0.07 ± 0.00	6.03 ± 0.20
IT 97K-573-2 (Yiisyandé)	44.11 ± 2.39 [p]	1.00 ± 0.05	1.64 ± 0.08	0.04 ± 0.00	3.12 ± 0.22
IT 98K-205-8 (Niizwé)	62.83 ± 1.82 [m,n]	1.04 ± 0.02	2.10 ± 0.05	0.04 ± 0.00	4.84 ± 0.12
Kondèsyoungo local	15.50 ± 0.61 [s,t]	0.28 ± 0.02	0.49 ± 0.04	0.01 ± 0.00	0.83 ± 0.04
KVx 30-309-6G	13.50 ± 1.14 [t]	0.35 ± 0.03	0.63 ± 0.06	0.01 ± 0.00	1.01 ± 0.10
KVx 396-4-5-2D	126.87 ± 2.5 [i]	3.67 ± 0.16	6.90 ± 0.17	0.09 ± 0.00	14.40 ± 0.32
KVx 402-5-2	202.18 ± 3.92 [f]	4.89 ± 0.29	9.49 ± 0.55	0.14 ± 0.01	20.12 ± 0.56
KVx 414-22-2	107.64 ± 3.11 [j,k]	1.80 ± 0.02	3.02 ± 0.03	0.08 ± 0.00	6.46 ± 0.14
KVx 421-2J	101.22 ± 11.57 [k]	2.16 ± 0.24	5.07 ± 0.52	0.07 ± 0.01	11.01 ± 0.96
KVx 442-3-25-SH (Komcallé)	17.26 ± 0.44 [s,t]	0.39 ± 0.02	0.72 ± 0.03	0.01 ± 0.00	1.31 ± 0.04
KVx 61-1	43.62 ± 2.05 [p]	1.15 ± 0.07	1.84 ± 0.1	0.05 ± 0.00	2.66 ± 0.17
KVx 65-114	26.61 ± 1.66 [q,r,s]	0.78 ± 0.06	1.32 ± 0.09	0.02 ± 0.00	2.45 ± 0.17
KVx 745-11P	392.39 ± 10.75 [c]	8.88 ± 0.35	11.50 ± 0.45	0.30 ± 0.01	22.61 ± 0.71
KVx 771-10G (Nafi)	46.07 ± 0.87 [o,p]	1.37 ± 0.03	1.89 ± 0.05	0.04 ± 0.00	3.48 ± 0.05
KVx 775-33-2G (Tiligré)	80.87 ± 0.65 [l]	2.39 ± 0.02	3.54 ± 0.05	0.06 ± 0.00	7.86 ± 0.27
KVx 780-1	35.40 ± 0.35 [p,q]	1.00 ± 0.03	1.83 ± 0.05	0.03 ± 0.00	3.30 ± 0.04
KVx 780-3	34.41 ± 0.64 [p,q]	0.98 ± 0.04	1.73 ± 0.08	0.02 ± 0.00	3.78 ± 0.09
KVx 780-4	20.86 ± 1.65 [r,s,t]	0.61 ± 0.02	1.07 ± 0.04	0.02 ± 0.00	2.19 ± 0.15
KVx 780-6	413.39 ± 7.76 [b]	10.95 ± 0.12	17.29 ± 0.13	0.29 ± 0.01	37.40 ± 1.28
KVx 780-9	299.02 ± 6.77 [e]	7.25 ± 0.01	12.86 ± 0.09	0.19 ± 0.00	30.44 ± 0.61
Labagela local	45.08 ± 0.99 [p]	0.93 ± 0.02	1.66 ± 0.05	0.05 ± 0.00	2.37 ± 0.07
Mougne	73.30 ± 2.22 [l,m]	1.58 ± 0.04	2.69 ± 0.03	0.05 ± 0.00	6.32 ± 0.12
Moussa local	30.47 ± 1.21 [q,r]	0.73 ± 0.02	1.31 ± 0.04	0.02 ± 0.00	2.49 ± 0.12
Niango local	57.14 ± 1.18 [n,o]	1.27 ± 0.03	2.29 ± 0.07	0.04 ± 0.00	5.43 ± 0.05
TVU 14676	555.61 ± 7.48 [a]	10.82 ± 0.21	19.76 ± 0.49	0.46 ± 0.02	36.37 ± 0.20
TZ-1(Gourgou)	147.15 ± 1.91 [h]	3.02 ± 0.03	5.06 ± 0.05	0.11 ± 0.00	10.51 ± 0.04

Data were expressed as mean ± SE. Means with different superscript along the row differs significantly ($P < 0.05$).

Table 3. Pearson correlation matrix for mineral elements and phytate content in cowpeas varieties.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
(1) Fe	1							
(2) Se	**0.215**	1						
(3) Zn	**0.861**	**0.255**	1					
(4) Na	0.112	0.041	0.110	1				
(5) Ca	**0.473**	**-0.243**	**0.415**	-0.083	1			
(6) Mg	**0.672**	-0.135	**0.689**	0.193	**0.671**	1		
(7) K	**0.501**	**-0.222**	**0.598**	0.048	**0.652**	**0.853**	1	
(8) Phytic Acid	0.114	**-0.356**	**0.207**	-0.198	0.204	**0.313**	**0.311**	1

in Bold, significative value (P < 0.05).

Significant correlation was observed amongst various mineral elements viz. iron, zinc, magnesium, potassium, calcium and selenium (r = 0.861, 0.672, 0.501, 0.473 and 0.215) respectively. Significant positive correlations were also found between grain Zn with Mg, K, Ca and Se concentrations (r = 0.689, 0.598, 0.415 and 0.255). No significant correlation was found between Na and the other mineral elements content in different cowpeas seeds. The Pearson correlation coefficient analysis revealed significant relationship between cowpeas grain Fe, Zn, Ca, Mg and K. These mineral elements might have the same genetic base and could be simultaneously improved by breeding (Velu *et al*., 2014). Exploring the genetic variation of cowpeas crop for mineral elements concentrations will help the breeding of mineral enriched cowpeas varieties and to improve the nutrition of the vast majority of the population.

Phytate content and molar ratios of dietary phytate to iron, zinc, calcium and phytate x calcium: zinc: As shown in Table 2, the composition of the seeds in phytate varies widely between the thirty varieties of cowpeas. The phytate content of the cowpeas genotypes varied from 555.610 ±7.48 to 13.502 ± 1.14 mg/100 g of seeds dw. TVU 14676 genotype possess the significant high content of phytate followed by the genotypes KV x 780-6, KV x 745-11P and 58-57. The genotypes KVx 30-309-6G, KVx 65-114, KVx 780-4, Komcallé, Kondesyoungo local and KVx 30-309-6G showed the low content of phytate. High genetic variation over of 40-fold difference in seeds phytate concentration was observed in these cowpeas varieties. Phytate, a common constituent of legume-derived foods has a negative effect on divalent mineral uptake such as zinc, iron, calcium, magnesium, manganese and copper (Kumar *et al*., 2010). However, to human health, phytate can have advantages. Numerous studies reported that phytate may have beneficial roles as an antioxidant, anti-cancer agent, anticarcinogen, against coronary heart disease, against diabetes mellitus, against HIV, against dental caries, against renal lithiasis, hypolipidaemic activity and antiplatelet activity (Kumar *et al*., 2010; Ma et al., 2007). The molar ratios of Phy:Fe, Phy:Zn , Phy:Ca and Phy x Ca: Zn have been studied to predict the potential mineral bioavailability. Twenty-one genotypes of cowpeas had molar ratios of Phy: Fe above the critical molar ratio 1. Only nine genotypes of cowpeas had Phy: Fe molar ration inferior to 1, which don't compromise the absorption of iron. The cowpeas genotypes KVx 780-6 and TVu 14676 had the highest values of Phy:Fe molar ration respectively of 10.95 ± 0.12 and 10.82 ± 0.21.

Two cowpeas varieties had Phy: Zn above 15, with the highest values for TVU14676 (19.76 ± 0.49) and KVx780-6 (17.29 ± 0.13) varieties. These Phy: Zn molar ratios showed that the phytate content doesn't compromise the absorption of zinc except for the genotypes TVU 14676 and KVX 780-6. The molar ratios Phy x Ca: Zn was also calculated. These ratios showed that the phytate level in cowpeas varieties don't compromise the zinc absorption with molar ratios below 200.

The dietary phytate x Ca: Zn molar ratio has been reported to be a more useful assessment of zinc bioavailability than the phytate: Zn molar ratio alone because of the potentiation effect of calcium on phytate (Kwun & Kwon, 2000). The molar ratios of phytate/calcium of all cowpeas varieties were < 0.17 except for the varieties TVU 14676, KV x 745-11P, KV x 780-6, 58-57, KV x 780-9 that the phytate content might be significantly inhibited calcium absorption.

From the Pearson correlation test, weak positive and significant correlations between phytate and zinc, phytate and magnesium and between phytate and potassium were found respectively of 0.207, 0.313 and

0.311. Phytate concentration was found not being correlated with iron content in 30 cowpeas varieties. However, the phytate concentration was negatively correlated with Se concentration ($P < 0.05$, $r = -0.356$). These findings suggest that it will be possible to breed the cowpea with low content in phytate and high iron and selenium levels. The mineral bioavailability of foods can be influenced to the amount of phytate, the chemical form in which the phytate is contained and the composition of the diet used (Grases *et al*., 2017). Reducing phytate level in cowpea could be a sustainable strategy to improve the iron, zinc and calcium value of cowpea.

CONCLUSION

High genetic diversity was found among the Burkina Faso cowpeas varieties in seeds Fe, Zn, Mg, Ca, Se, K and Na concentrations. *V. unguiculata* has a great genetic potential to be exploited since it shows great variability in mineral contents. Many of these variations can be generated by conventional genetic breeding to attend the nutritional needs in developing countries. This study provides important information for breeding cowpeas varieties with the capacity of simultaneous accumulation of some essential mineral and low phytate content in edible grains. However, further studies in different locations are needed in order to evaluate the environmental effect on mineral elements and phytate concentrations in the cowpea's varieties used in this work. More biological assays must be conducted to better characterize Fe, Zn and Ca bioavailability in various cowpeas seeds.

ACKNOWLEDGMENTS

This research has been supported by TWAS under individual Fellowship Grant Nº 14-218 RG/BIO/AF/AC_I UNESCO FR: 24028592 given to the first author.

REFERENCES

Ficco, D.B.M., C. Riefolo, G. Nicastro,V. De Simone, A.M. Di Gesù,R. Beleggia, C. Platani, L. Cattivelli and P. De Vita. 2009. Phytate and mineral elements concentration in a collection of Italian durum wheat cultivars. *Field Crops Research* 111 (3): 235–242. Available at: https://doi.org/10.1016/j.fcr.2008.12.010

Gharibzahedi, S.M.T., and S.M. Jafari. 2017. The importance of minerals in human nutrition: Bioavailability, food fortification, processing effects and nanoencapsulation. *Trends in Food Science and Technology* 62: 119–132. Available at: http://dx.doi.org/10.1016/j.tifs.2017.02.017.

Grases, F., R.M. Prieto and A. Costa-bauza. 2017. Dietary Phytate and Interactions with Mineral Nutrients. Gutiérrez O., K. Kalantar-Zadeh, R. Mehrotra. (eds) Clinical Aspects of Natural and Added Phosphorus in Foods. Nutrition and Health. Springer, New York, NY 175–183. Available at https://doi.org/10.1007/978-1-4939-6566-3_12

Gupta, U.C., and S.C. Gupta. 2014. Sources and Deficiency Diseases of Mineral Nutrients in Human Health and Nutrition: A Review. *Pedosphere* 24 (1): 13–38. Available at: http://dx.doi.org/10.1016/S1002-0160(13) 60077-6.

Ijarotimi, O.S., T.N. Fagbemi and O.F. Osundahunsi. 2015. Determination of nutrient compositions , glyceamic index and ant-diabetic potentials of multi- plant based functional foods in rats. *J.Food Pharm.Sci* 3: 55-63. Available at https://doi.org/10.14499/jfps

Kamis, Z., R. Yaakub, S.K. Ong and Kassim. 2015. Sodium content of processed foods in Brunei Darussalam. *J Health Res* 29 (3): 153–64. Available at https://www.tci-thaijo.org/index.php/jhealthres/article/view/97164/75689

Kruger, J., R. Minnis-Ndimba, C. Mtshali, A. Minnaar. 2015. Novel in situ evaluation of the role minerals play in the development of the hard-to-cook (HTC) defect of cowpeas and its effect on the in vitro mineral bioaccessibility. *Food Chemistry* 174: 365–371. Available at: http://dx.doi.org/10.1016/j.foodchem.2014.10.134.

Kumar, V., A.K. Sinha, H. P.S. Makkar and K. Becker. 2010. Dietary roles of phytate and phytase in human nutrition: A review. *Food Chemistry* 120 (4): 945–959. Available at: http://dx.doi.org/10.1016/j.foodchem.2009.11.052.

Kwun, I., and C. Kwon. 2000. Dietary Molar Ratios of Phytate : Zinc and Millimolar Ratios of Phytate X Calcium : Zinc in South Koreans. *Biological Trace Element Research* 75: 29–41.

Lazarte, C. E., N. Carlsson, A. Almgren, A. Sandberg, Y. Granfeldt. 2015. Phytate, zinc, iron and calcium content of common Bolivian food, and implications for mineral bioavailability. *Journal of Food Composition and Analysis* 39: 111–119. Available at: http://dx.doi.org/10.1016/j.jfca.2014.11.015.

Ma, G., Y. Li, Y. Jin, F. Zhai, F.J. Kok and X. Yang. 2007. Phytate intake and molar ratios of phytate to zinc , iron and calcium in the diets of people in China. *European Journal of Clinical Nutrition* 61: 368–374.

Obi, C., and J. Okoye. 2017. Effects of Boiling and Autoclaving on the Chemical Composition and Functional Properties of *Mucuna Flagellipes* Seed Flours. *International Journal of Innovative Food, Nutrition & Sustainable Agriculture* 5 (2): 18–24. Available at http://seahipaj.org/journals-ci/june-2017/IJIFNSA/full/IJIFNSA-J-3-2017.pdf

Ogunyinka, B. I., B.E. Oyinloye, F.O. Osunsanmi, A.P. Kappo and A.R. Opoku. 2017. Comparative study on proximate, functional, mineral, and antinutrient composition of fermented, defatted, and protein isolate of *Parkia biglobosa* seed. *Food Science and Nutrition* 5 (1): 139–147.

Olaleke, A.M., O. Olorunfemi and T.E. Akintayo. 2006. Compositional evaluation of cowpea (*Vigna unguiculata*) and scarlet runner bean (*Phaseolus coccineus*) varieties grown in Nigeria. *Journal of Food, Agriculture and Environment* 4 (2): 39–43.

Onabanjo, O.O., andC.R.B. Oguntona. 2003. Iron, zinc, copper and phytate content of standardized Nigerian dishes. *Journal of Food Composition and Analysis* 16 (6): 669–676. Available at https://doi.org/10.1016/S0889-1575(03)00063-2

Pfeiffer, W.H., and B. McClafferty. 2007. HarvestPlus: Breeding crops for better nutrition. *Crop Science* 47: s88–s105.

Santos, C.A., and L. Boiteux, L. 2013. Breeding biofortifed cowpea lines for semi-arid tropical areas by combining higher seed protein and mineral levels. *Genetics and Molecular Research* 12 (4): 6782–6789. Available at http://dx.doi.org/10.4238/2013.December.16.4

Souza, G.A., J.J. Hart, J.G. Carvalho, M.A. Rutzke, J.C. Albrecht, L.R.G. Guilherme, L.V. Kochian and L. Li. 2014. Genotypic variation of zinc and selenium concentration in grains of Brazilian wheat lines. *Plant Science* 224: 27–35. Available at https://doi.org/10.1016/j.plantsci.2014.03.022

Velu, G., I. Ortiz-Monasterio, I. Cakmak, Y. Hao, R.P. Singh. 2014. Biofortification strategies to increase grain zinc and iron concentrations in wheat. *Journal of Cereal Science*, 59 (3): 365–372. Available at: http://dx.doi.org/10.1016/j.jcs.2013.09.001.

Welch, R.M., and R.D. Graham. 2002. Breeding crops for enhanced micronutrient content. *Plant and Soil* 245: 205–214.

Wheeler, E., R.E. Ferrel. 1971. A method for Phytic Acid Determination in Wheat and Wheat Fractions. *Cereal Chemistry* 48: 312–320. Available at https://www.aaccnet.org/publications/cc/backissues/1971/Documents/Chem48_312.pdf

Zia-Ul-Haq, M., S. Ahmad, R. Amarowicz and V. De Feo. 2013. Antioxidant activity of the extracts of some cowpea (*Vigna unguiculata* (L) Walp.) cultivars commonly consumed in Pakistan. *Molecules* 18 (2): 2005–2017.