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Essential Mineral Elements Profile of 22 Accessions of Okra (*Abelmoschus* spp (L.)) From Eight Regions of Ghana

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Abstract

Five (5) essential macro, three (3) micro and two (2) trace mineral elements were determined in fresh fruits of twenty-two (22) accessions of okra using Instrumental Neutron Activation Analysis (INAA). These were correlated to assess the level of associations existing between these elements. Concentrations of these elements were juxtaposed with their recommended daily dietary intake (RDI) in the individual accessions of okra and their variability with other traits examined for future improvement works towards breeding for high or low micro nutrient containing variety (ies).

Keywords: *Abelmoschus* spp, accessions, INAA, mineral elements, health risk, RDI, nutrition

1. Introduction

Okra, (*Abelmoschus* spp (L.)), is prominently featured in nearly every market in Africa. In Ghana, it is the fourth most popularly patronised vegetable after tomatoes, pepper and garden eggs (Oppong-Sekyere et al., 2012; Sinnadurai, 1973). The world okra production, as of 2010, was estimated at 6.9 million tonnes with Asia leading the production by 75.92% followed by Africa (23.41%) and the Americas (0.54%) (FAOSTAT, 2012). On the whole, India is the leading producer of okra with over 70% of the total world production, followed by Nigeria, Pakistan, Sudan, Ghana, Egypt and Iraq (FAOSTAT, 2012; Gulsen et al., 2007). Okra is usually consumed fresh and in sauces and soups. It is used by the growing fast food, hotel and restaurant industry in Asia, the Americas, Africa and many other parts of the globe (Lamont Jr., 1999; Tyler et al., 1989), just like any other vegetable. Okra is consumed almost daily and traded by a broad range of market participants worldwide.

In Ghana, okra is traded in the fresh state in almost all markets during the rainy season and in a dehydrated form during the dry seasons. Essential mineral elements are elements that are indispensable to the human body and yet cannot be produced by the body. Approximately, the edible portion of the fruit contains 88.6 g of water, 36 kcal energy, 2.10 g protein, 8.20 g carbohydrate, 0.20 g fat, 1.70 g fibre, together with small amounts of β-carotene (185.00 μg), riboflavin (0.08 mg), thiamine (0.04 mg), niacin (0.60 mg), ascorbic acid (47.00 mg) (Kolawole et al., 2011; Saifullah & Rabbani, 2009). Okra is also a good source of vitamin B, some essential minerals (Lamont Jr., 1999), rhamnose (22%), galacturonic acid (27%) and amino acids (11%) (Benchasri, 2012).

2. Materials and Methods

2.1 Experimental Site

The experiment was conducted at the Ghana Research Reactor 1 (GHARR-1), the Nuclear Agriculture Research Centre (NARC) and the Radiation Technology Centre (RTC) of the Ghana Atomic Energy Commission, Kwabenya (Accra), Ghana. Instrumental Neutron Activation Analysis (INAA) was employed for the determination of variability in composition of mineral elements concentration in the fresh fruits of 22 accessions of okra assembled from eight geographical regions of Ghana.

2.2 Okra Sample Preparation for Elemental Analysis

Five (5) fruits of each of the 22 accessions were sliced into several pieces and put into plastic bowls and lyophilised (freeze-dried) for 48 hrs in a CHRIST FREEZE DRYER before blending into fine powder. Samples were pulverised and put into clean plastic containers and shaken thoroughly to ensure uniformity before weighing. 200 mg of each sample (accession) was weighed into small polyethylene vials, labelled and hot sealed. The polyethylene capsules of diameter 1.2 cm and height 2.35 cm containing the samples were in turn, each put into a bigger polyethylene capsule of diameter 1.6 cm and height 5.5 cm (Rabbit capsule). Standard Reference material 1547 Peach Leaves from the National Institute of Technology and 1547 Citrus Leaves and blanks were equally prepared in the same manner as the test samples. Each sample was then irradiated by means of the Ghana Nuclear Research Reactor (GHARR-1) for 1 minute to detect short radionuclides. This was immediately followed by quantification of the samples.

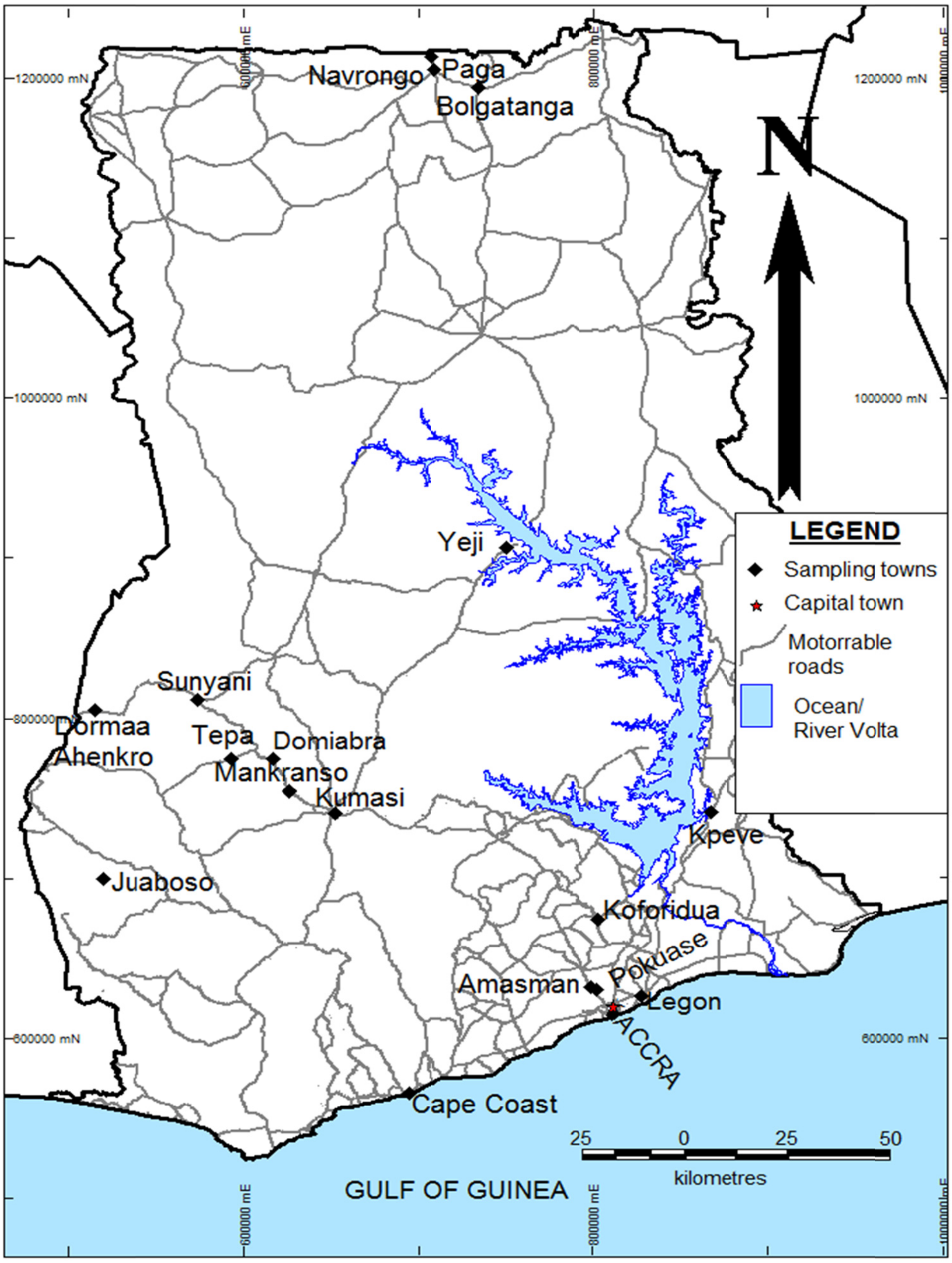

Figure 1. Map of Ghana showing locations where various accessions were collected

2.3 Sample Irradiation and Counting

Lyophilised fresh fruits of okra and controls were irradiated in the Ghana Research Reactor (GHARR-1) at the Ghana Atomic Energy Commission, operating at 15 KW at a thermal flux of 5×10^{11} $n\cdot cm^{-2}\cdot s^{-1}$. Samples were transferred into irradiation sites via pneumatic transfer system at a pressure of 0.6 Mpa. The irradiation was categorised according to the half-life of the element of interest. For, ^{27}Mg, ^{66}Cu, and ^{38}Cl samples were irradiated for two minutes and counted for ten minutes. For medium lived radionuclides like K, Na, samples were irradiated for one hour and delayed for 24 hrs with ten minutes counting. After the irradiation, radioactivity measurements of induced radionuclide were performed by a PC-based γ-ray spectrometry set-up. This consisted of an n-type HPGe detector coupled to a computer based multi-channel analyser (MCA) via electronic modules. The relative efficiency of the detector is 25% with energy resolution of 1.8 keV at a γ-ray energy of 1332 keV of ^{60}Co. Through appropriate choice of cooling-time, detector's dead time was controlled to be less than 10%. Identification of γ-ray of product radionuclide was done through the energies and quantitative analysis of the concentration was achieved using the γ-ray spectrum analysis software, ORTEC MEASTRO-32.

2.4 Data Analyses

The Completely randomised design (CRD) was used with three replicates. They were evaluated for statistical significance with one-way analysis of variance (ANOVA) and means separated by the Duncan's multiple range test (Statgraphics (2010) Centurion XVI, version 16.1.11, USA) and expressed as the Mean upon three independent analyses. A p-value of 0.05 or less was considered as statistically significant.

3. Results and Discussion

3.1 Concentrations of Ten Essential Elements in 22 Accessions of Abelmoshus spp L.

Concentrations of five essential macro elements (Ca, Cl, K, Mg and Na), three micro elements (Al, Cu and Mn) and two trace elements (As and Br) detected by Instrumental Neutron Activation Analysis (INAA) in 22 accessions of okra are shown in Table 1. Yeji-Local registered the minimum (10.12±1.52 mg/kg) while Asontem-NV recorded the maximum (95.18±13.79 mg/kg) Ca content. Concentration of Cl recorded among the various okra accessions ranged from 10.85±1.63 mg/kg in Cape to 95.45±14.32 mg/kg in Mamolega. Similarly, the accession Indiana recorded the minimum concentration (13.42±2.01 mg/kg) of K with Nkran Nkuruma recording the maximum concentration (97.43±14.61 mg/kg). Asontem NV had the minimum concentration of Mg (40.09±6.01 mg/kg) while Asontem-BAR registered the maximum content (61.52±9.23 mg/kg). Asontem-ASR registered the minimum concentration (16.32±2.45 mg/kg) of Na while Mamolega recorded the maximum concentration (778.5±11.60 mg/kg).

Table 1. Concentration of ten mineral elements in 22 accessions of Okra (mg/kg*)

	Macro elements					Micro elements		Trace elements		
Accession	**Ca**	**Cl**	**K**	**Mg**	**Na**	**Al**	**Cu**	**Mn**	**As**	**Br**
Agric Type I	82.25±12.34	54.81±8.22	27.21±4.08	45.09±6.76	189.0±28.24	32.84±5.29	nd	14.59±2.95	1.27±0.19	20.01±3.00
Agric Short Fruit	10.34±1.55	69.17±10.37	92.14±13.82	48.57±7.29	205.26±30.79	42.72±6.88	nd	15.53±2.92	Nd	21.56±2.23
Asante Type II	90.92±13.64	71.28±10.69	19.07±2.86	50.10±7.52	279.3±40.99	37.76±6.04	nd	17.07±3.28	1.57±0.24	25.65±3.85
Asontem NV	**99.18±13.79***	81.39±12.20	16.04±2.41	40.09±6.01	190.1±28.52	47.96±7.67	nd	15.68±2.99	1.88±0.28	29.96±4.49
Asontem-ASR	89.26±13.39	61.53±9.23	23.80±3.57	54.75±8.21	16.32±2.45	33.80±5.41	nd	15.56±2.93	10.30±1.55	15.54±2.33
Asontem-BAR	11.13±1.67	88.19±13.23	19.81±2.97	**61.52±9.23***	191.5±28.25	37.17±5.95	186.5±27.98	14.45±2.77	1.99±0.30	31.64±4.75
Asontem-ER	72.59±10.87	62.11±9.32	18.31±2.75	42.95 ±6.44	277.0±41.55	42.50±6.80	nd	13.31±2.64	2.33±0.35	38.42±5.76
Asontem-GAR	96.21±14.43	93.78±14.07	17.88±2.68	47.59±7.14	590.4±88.56	35.96±5.75	nd	20.35±3.81	1.62±0.24	25.72±3.86
Atomic	76.91±11.54	36.84±5.53	16.97±2.55	48.53±7.28	362.6±54.39	37.34±5.94	165.6±24.84	16.47±3.12	3.25±0.49	51.86±7.78
Cape	11.71±1.76	10.85±1.63	19.48±2.92	54.70±8.21	385.6±57.16	38.08±6.13	**424.5±63.67***	25.21±4.84	2.24±0.34	36.20±5.43
Clemson Spineless	73.08±10.96	51.37±7.71	76.43±11.46	43.96±6.59	221.41±33.21	51.39±8.17	nd	17.07±3.12	Nd	41.62±6.24
Mean	64.31±9.64	64.73±9.71	32.06±4.81	49.99±7.49	319±42.97	42.45±6.77	233.61±9.56	17.8±3.33	2.84±0.43	34.41±5.25
CV (%)	187.74	269.75	17.33	23.01	6.14	60.55	45.57	193.13	82.04	15.73
RDI	500-1200	100-500	2000	320-420	2400-5175	2	0.4-1.2	2-5		2-5

*Value bolded and asterisked refers to the highest concentration for a particular element; ± = standard error of the mean of mineral element concentration in the accession. CV = Coefficient of Variation; RDI = recommended daily intake: (Source = Dietary Reference, 1991); nd = not detected.

Table 1 (Cont'd)*

	Macro elements					Micro elements			Trace elements	
Accession	Ca	Cl	K	Mg	Na	Al	Cu	Mn	As	Br
Indiana	68.39±10.26	46.27±6.94	13.42±2.01	44.57±6.69	521.32±78.20	31.16±4.67	Nd	36.35±5.45*	Nd	18.45±2.77
Juaboso	11.69±1.75	83.44±12.52	19.62±2.94	59.59±8.94	218.3±32.75	35.26±5.64	263.4±39.51	24.01±4.29	1.91±0.29	31.42±4.72
Kortebortor-ASR	94.23±14.13	43.01±6.45	21.14±3.17	46.86±7.03	170.0±25.50	36.53±5.88	85.26±12.79	11.00±2.49	2.27±0.34	36.10±5.42
Kortebortor-BAR	89.49±13.42	58.06±8.71	20.09±3.01	51.47±7.72	171.1±25.67	37.89±6.06	Nd	13.88±2.58	1.38±0.20	22.67±3.40
Labadi	10.63±1.59	85.52±12.83	23.14±3.47	55.76±8.36	316.78±47.52	41.39±6.62	276.4±41.46	20.48±3.63	Nd	27.43±4.11
Legon Fingers	90.61±13.59	65.08±9.76	15.32±2.30	48.95±7.34	570.7±85.61	43.57±6.93	Nd	15.50±2.88	2.07±0.31	34.67±5.20
Mamolega	90.9±13.63	95.48±14.32*	40.79±6.12	50.91±7.64	778.5±11.60*	77.41±12.3*	Nd	18.03±3.55	6.47±0.97	104.6±15.69*
Nkran Nkuruma	84.79±12.71	52.89±7.93	97.43±14.61*	51.27±7.69	336.42±50.46	34.69±5.59	Nd	15.89±2.86	Nd	53.18±7.98
Volta	68.63±10.29	61.10±9.17	18.45±2.77	45.94±6.89	415.26±62.29	38.11±6.10	Nd	11.63±2.61	Nd	28.65±4.30
Wune mana	88.37±13.26	72.54±10.88	23.33±3.49	50.96±7.64	223.4±33.51	70.11±11.15	Nd	17.27±3.51	2.18±0.33	34.75±5.21
Yeji-Local	10.12±1.52	78.85±11.83	65.47±9.82	55.71±8.36	387.82±58.17	50.21±7.98	Nd	22.77±4.08	Nd	46.78±7.02
Mean	64.31±9.64	64.73±9.71	32.06±4.81	49.99±7.49	319±42.97	42.45±6.77	233.61±9.56	17.8±3.33	2.84±0.43	34.41±5.25
CV (%)	187.74	269.75	17.33	23.01	6.14	60.55	45.57	193.13	82.04	15.73
RDI	500-1200	100-500	2000	320-420	2400-5175	2	0.4-1.2	2-5		2-5

*Value bolded and asterisked refers to the highest concentration for a particular element; ± = standard error of the mean mineral element concentration in the accession. CV = Coefficient of Variation; RDI = recommended daily intake: (Source = Dietary Reference, 1991); nd = not detected.

With respect to the micro elements, Indiana recorded the minimum Al concentration (31.16 ±4.67 mg/kg) while Mamolega recorded the maximum (77.41 ± 12.31 mg/kg). Concentration of Arsenic (As) ranged from 1.24±0.34 mg/kg in Cape to 10.30±2.45 mg/kg in Asontem-ASR; Br concentration ranged from 15.54±2.33 mg/kg (Asontem-ASR) to 104.6±15.69 mg/kg (Mamolega). Similarly, Kortebortor-ASR recorded the minimum Cu concentration (85.26±12.79 mg/kg) while Cape again had the maximum (424.5±63.67 mg/kg). On the other hand, Indiana registered the maximum Mn concentration (36.35±5.45 mg/kg) with the minimum registered by Kortebortor-ASR (11.00±2.49 mg/kg). No single accession recorded the maximum concentration for all the elements analysed though the accession Asontem-BAR which recorded maximum concentrations of Mg and Cl, also recorded significantly high concentrations of other elements analysed.

On the whole, there were high variabilities among the okra accessions for concentrations of all five essential macro elements in the edible fruits as detected using INAA. Variabilities among accessions for concentration of the three micro elements and two trace elements in the fresh fruits were also high. The concentrations of Cu and As in some accessions were below levels detectable using INAA.

Calcium is one of the predominant essential elements in foods. All the accessions recorded very low amounts of calcium compared to the recommended daily allowance of 500-1200 mg/kg (Oduro et al., 2008; http://nutritiondata.self.com/facts/cereal-grains-and-pasta/5707/2). In a similar study, Ismail et al. (2011) using Atomic Absorption Spectrometry (AAS) reported higher concentrations of Ca in okra (210 mg/kg), tomato (335 mg/kg), chilli pepper (305 mg/kg), onion (265 mg/kg), cucumber (180 mg/kg) and carrot (220 mg/kg). Howe et al. (2005) working in Ethiopia and using Neutron Activation Analysis (NAA) as well as Flame and Graphite Furnace Atomic Absorption Spectrophotometry (FGFAAS) in a study of elemental composition of five categories of Jamaican foods reported 360 mg/kg Ca as against 139 mg/kg; 133 mg/kg; 135 mg/kg and 7.65 mg/kg Ca recorded for same foods in Denmark, UK, USA and Nigeria, respectively. Accessions with significant concentration of this element could be developed for use in supplementation of other sources of Ca to meet the recommended dietary intake.

Chorine is an essential nutrient in human nutrition required for healthy functions of nervous and digestive systems. It is present in crustal rock at a concentration of about 170 mg/kg and preferentially adheres to soil particles. The concentrations of Cl recorded elsewhere for fresh broccoli, cucumber, melon, green onion, chilli pepper, tomato and apples ranged from 100-150 mg/kg; 100-150 mg/kg; 100-150 mg/kg; 100-150 mg/kg; 250-400 mg/kg; 200-350 mg/kg and 100-1500 mg/kg, respectively (Suslow, 2006). These values are higher than those recorded in this study. Concentration of chlorine in the accessions studied was highly variable. This could be attributed to influence of soil geochemical processes, anthropogenic influences and previous agronomic practices on experimental site (Suslow, 2006).

Variability in concentration of K among the accessions was low and the individual values were also below the RDI. However, these values were above those reported by Benchasri (2012) for okra and Adotey et al. (2009) for tomato. Similarly, variability in concentration of Mg among accessions recorded in this study was also low. Values recorded were below those reported for okra (323 mg/kg); mango (326 mg/kg); carrot (2970 mg/kg); onion (1705 mg/kg); cucumber (392 mg/kg); tomato (418 mg/kg) and chilli pepper (236 mg/kg) (Ismail et al., 2011) but higher than those reported by Adotey et al. (2009) and Zaichick (2002) for tomato.

Results of this study indicate that okra pods contain high levels of Na compared to other elements. This is consistent with the report by Kumar et al. (2010). Ismail et al. (2011) reported varying Na concentrations in okra (1240 mg/kg); guava (580 mg/kg); mango (4000 mg/kg); cucumber (5250 mg/kg); tomato (7350 mg/kg); chilli pepper (4050 mg/kg); onion (4600 mg/kg) and carrot (4900 mg/kg) which compare well with Na concentrations in the current study. Variability among accessions for the concentration of Na was very low.

Concentrations of all three micro elements (Al, Cu and Mn) detected were variable among the accessions. Quartey et al. (2012) and Adotey et al. (2009) also reported high variabilities in concentrations of these elements in tomato. The concentrations of Al recorded for all accessions were comparatively higher than values recorded for clover (23.6 mg/kg), oats (7.3 mg/kg), bean (5.1 mg/kg), green lentil (6.6 mg/kg), spinach (12.6 mg/kg), corn (11.90 mg/kg), red lentil (3.7 mg/kg) and rice (8.4 mg/kg) as reported by Hicsonmez et al. (2012). On the other hand, Mn levels reported in okra (323 mg/kg); mango (326 mg/kg); carrot (2970 mg/kg); onion (1705 mg/kg); cucumber (392 mg/kg); tomato (418 mg/kg) and chilli pepper (236 mg/kg) by Ismail et al. (2011) are higher than those reported in this study.

Content of Cu in the fresh fruits of okra was detectable in only six out of the 22 accessions with a mean of 233.6 mg which far exceed the RDI. Differential abilities of some accessions to uptake and accumulate Cu in the fruits may account for the results obtained. Ismail et al. (2011) recorded Cu concentrations of 100 mg/kg; 100 mg/kg; 130 mg/kg; 170 mg/kg; 500 mg/kg; 900 mg/kg; 1400 mg/kg and 1400 mg/kg in okra, cucumber, tomato, chilli pepper, guava, mango, onion and carrot respectively in Pakistan. Copper is one of the essential micronutrients, hence its adequate supply in vegetables must be supplemented by application of synthetic or organic fertilisers (Itanna, 2002). There was high variability in the concentration of Mn among the accessions. Values obtained far exceed the RDI.

Concentration of As in the fresh fruits of the accessions exceed the range (0.005-0.54 mg/kg) reported by Al Rmalli et al. (2005) for vegetables imported from Bangladesh comparable to values for freshwater fish (0.097-1.318 mg/kg). The As content of the vegetables from UK was approximately 0.002 to 0.003 mg/kg lower than those observed for the vegetables imported from Bangladesh (Al Rmalli et al., 2005) comparing very well with results of this study. The high As content in accessions of *Abelmoschus* spp (L.) could have originated from the seeds or the water used in the germination process. The accessions of okra appear to contain relatively high levels of As, although uptake in general is contingent on both plant species and elemental availability (She & Kheng, 1992). As is a highly toxic element and its presence in food composites is a matter of concern to the well-being of both humans and animals. Source of water, industrial effluents and contaminated water for irrigating farmland have become notorious sources of heavy metal pollution of agricultural lands. As could have been added to the soil water system from effluents emanating from the ceramic and glass industries of Aburi and the Akuapim ridge of the city of Accra. Bioaccumulation of As would be hazardous to humans and animals because of its perceived relationship to cancer, arteriosclerosis and chronic liver disease.

Variability in the concentrations of Br among the 22 okra accessions was low. This contrasts with results reported by Howe et al. (2005) for fruits and leafy vegetables (0.07-5.5 mg/kg) in Jamaica and UK, and also by far exceeds the RDI for Br (Dietary Reference, 1991). This is crucial as a result of the emerging status of okra (*Abelmoschus* spp (L.) as a non-traditional export crop in meeting acceptable international export standards. In general, variability in concentrations of the various elements among the accessions may be attributable to genotypic differences with respect to mineral uptake and accumulation and also influence of geochemical reactions within the soil at site such as speciation, soil-to-plant interactions as well as anthropogenic activities in and around the experimental site.

3.2 Association Between Mineral Elements

Table 2 shows the association between pairs of elements in the accessions analysed. Ca showed strong and positive association with three other elements Cl, Mg and Cu but was negatively correlated with Na, Al, As, Br and Mn. Its association with K was very weak though positive. Cl was moderately correlated with four elements, K, Mg, Na and Cu but negatively associated with Al, As and Mn. Its association with Br was very weak though positive. K exhibited positive association with the other four macro elements Ca, Cl, Mg and Na all of which were not significant. Similarly, it exhibited positive association with Br and Cu but was weakly and negatively associated with Al, As and Mn. Mg was significantly and positively associated with Ca but was negatively correlated with Na, Al, As and Mn but positively correlated with Br. Na was moderately and strongly associated with K and Br respectively. It was however, weakly associated with the rest of the elements. There was no positive significant association between Al and the rest of the elements. Similarly, association between As and the rest of the elements was mostly negative and weak. There was a strong association between Br and K as well as Na. Other associations were moderate or weak and negative. Relationships between Cu and Na as well as Al were weak though positive. The same element was weakly and negatively correlated with the rest of the elements except Ca which showed negative but moderate association.

Table 2. Correlations among ten mineral elements in 22 accessions of *Abelmoschus* spp (L)*

Mineral element	Ca	Cl	K	Mg	Na	Al	Cu	Mn	As	Br
Ca										
Cl	0.732									
K	0.101	0.330								
Mg	0.687	0.464	0.017							
Na	-0.137	0.290	0.411	-0.105						
Al	-0.367	-0.219	-0.032	-0.237	0.333					
Cu	0.636	0.444	0.175	0.565	-0.064	-0.164				
Mn	-0.442	-0.165	-0.010	-0.221	0.200	0.225	-0.141			
As	-0.015	-0.089	-0.102	-0.416	-0.238	0.014	-0.200	-0.170		
Br	-0.034	0.192	0.516	0.033	0.606	-0.063	-0.001	-0.125	-0.191	

P (≤0.05) is considered significant.

The strong associations between Ca and Cl as well as Mg are desirable as these elements are required in relatively large amount in the diets of humans (Hicsonmez et al., 2012). This suggests that it may be possible for the breeder to simultaneously select for higher concentrations of these pairs of elements in a breeding programme involving biofortification. Similarly, strong correlations between Cu and Ca as well as Mg suggest that positive gains may be made by the breeder in selecting for either pair of elements.

Historically, international breeding efforts in okra have been oriented towards intensive cultivation with high production in a short period (early maturity) and wide adaptation (photoperiod insensitivity, resistance to insects and diseases) (Benchasri, 2012). However, the importance of the quality of food source for reducing micro nutrient deficiencies has assumed prominence of late. There is now greater recognition of the global prevalence of many forms of micro nutrient malnutrition (National Academies Press, 2006). Hence, enhancing nutritional quality through diet selection holds great prospects of success in the near future.

Okra has no intraspecific barrier to crossability (Ahiakpa et al., 2013; Anonymous, 2010). It is a good candidate for inclusion in many diets by virtue of the significant concentration of several mineral elements in its edible fruits. Superior lines such as Mamolega, Yeji-Local, Asontem-BAR, Clemson spineless, Cape, Atomic, Asontem-GAR, Indiana and Legon fingers may be selected for future hybridisation work aimed at further improvement in mineral element contents alongside fresh fruit yield and other desirable traits.

4. Conclusions

Ten essential mineral elements were detected among the accessions with varying prevalence levels indicating high level of genetic variability among the accessions with respect to concentrations of these elements in their edible fruits. Concentrations of micro and trace elements (Al, As, Br, Cu and Mn), in all accessions were above their recommended daily dietary intake (RDI); therefore, excess intake of these varieties could pose health risk to consumers. However, concentrations of the macro elements (Ca, Cl, K, Mg and Na) were below their RDI (s). Hence, consumption of okra ought to be supplemented by other food sources of these elements in order to meet their RDIs. Three local (Mamolega, Nkran Nkuruma, Asontem-BAR) and one exotic (Indiana) accessions may be selected as parents for future breeding work aimed at concentrating optimum levels of several essential elements in a single variety together with high yield and adaptation to local environmental conditions. Strong positive associations existing between most pairs of elements contained in the accessions may be key in future breeding work involving biofortification, as selecting for one element may imply simultaneous selection of another.

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