Determination of Some Mineral Components of Cowpea (*Vigna unguiculata* (L.) Walp) Using Instrumental neutron activation analysis.

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Abstract

Some mineral elements in the seeds of the cowpea were determined using instrumental neutron activation analysis. The cowpea cultivars were made up of improved varieties (Soronko, Gbeho, Ayiyi, Asontem, Asontem1, Bengpla, Asetenapa and Adom), farmers' accessions (87/7, 87/1, 87/27, 87/147, 87/34, 87/49, 87/83, 87/157, 87/149, 87/30, 87/153, 96/046, 87/137, 96/129, BTB 96/091, OAA 96/30, BTB 96/054), and experimental materials (IT870-677-2, Caroni, Kaase Market, 1977 and 1239). A total of 14 elements (Al, Ca, Mg, V, Mn, Br, Cl, K, Na, Zn, Cu, Ta, Si and In) were detected in the seeds of the 30 cowpea cultivars. Five of the elements (Na, K, Mg, Ca and Cl) identified are classified as major elements in the human body, while four (Mn, Zn, V, Si, Cu and I) are trace elements. The major elements K, Na, Ca, Mg and Cl were detected in high concentration in cultivars 96/129, 87/137, Ayiyi, 87/34 and 87/49, respectively. The trace elements Mn, Zn, V, Si, Cu and Al were detected in high concentration in cultivars 87/34, 87/27, 87/34, Bengpla, 87/34 and 87/34, respectively. From the results the following accessions could be selected and incorporated into a cowpea mineral nutritional improvement programme: 96/129, 87/137, Ayiyi, 87/34, 87/49 and 87/27. The presence of the five major elements and the trace elements indicates that cowpea has a rich source of mineral elements and, therefore, can be used to improve the diet of both humans and livestock.

Introduction

Cowpea is an important tropical legume crop of African origin and has become an integral part of the traditional cropping system, particularly in the semi-arid West African savanna (Steele, 1975). Africa alone accounts for 7.5 million hectares of the estimated world total area, which is about 10 million ha. Of the 7.5 million ha, about 70% lies in West and Central Africa (Singh *et al*., 1996). The crop is considered the second most important food grain legume and constitutes a cheap source of plant protein for humans. The plant also provides feed, forage, hay and silage for livestock. It serves as green manure and cover crop for maintaining soil productivity. As food, the fresh seeds and immature pods of cowpea are eaten as spinach. A symbiosis occurs between cowpea and several *Rhizobium* spp. in which nodules are formed that fix atmospheric nitrogen. The crop also compensates for the loss of nitrogen removed by cereals when intercropped with them.

Chemical composition of the cowpea seeds corresponds with that of most edible legumes. Mature seeds contain per 100 g edible portion: carbohydrate 56-66 g, protein 22–24 g, water 11 g, crude fibre 5.9–7.3 g, ash 3.4–3.9 g, fat 1.3–1.5 g, phosphorus 0.146 g, calcium 0.104–0.076 g, and iron 0.005 g. The seeds also contain small amounts of β-carotene equivalents, thiamin, riboflavin, vitamin A, niacin, folic acid and ascorbic acid. Cowpea raw leaves contain per 100 g edible portion: water 85.0%, energy 44 cal, protein 44 g, fat 0.3 g, calcium 256 mg, phosphorus 63 mg, iron 5.7 mg, β-carotene 2.4 mg, thiamin 0.20 mg, riboflavin 0.37 mg, niacin 2.1 mg and ascorbic acid 56 mg (Pandey & Westphal, 1989). Twenty-one inorganic elements, made up of six major minerals (Na, K, Mg, Ca, P, and Cl), and 15 trace elements (As, Co, Cu, F, Fe, I, Mn, Mo, Ni, Se, Si, Sn, V and Zn), are now considered as being essential to human life (Linder, 1991).

From the literature, elemental composition of various cowpea accessions in Ghana is not known, though the crop serves as a good and cheap source of plant protein for school children, pregnant women, convalescents and all adults. Instrumental neutron activation analysis (INAA) has been used in elemental composition analysis of various environ-mental, biological and food samples (Sarfor-Armah *et al*., 2000). The technique has been used in the determination of nutrient elements in commercial tea from Nigeria (Jonah & Williams, 2000) and cassava cultivars from Ghana (Danso *et al*., 2001), and its application for similar analysis in the cowpea is highly recommended.

With the exception of calcium, iron and potassium, which have already been detected, the information contained in this paper will provide additional information on the nutritive value of the cowpea cultivars. Of special mention are the minor elements. The information will also enhance the cowpea breeding programme in Ghana and other parts of the West African sub-region. This paper, therefore, reports on the determination of the mineral composition of 30 cowpea cultivars by INAA.

Materials and methods

Plant materials and preparation

Seeds of 30 different cowpea cultivars were used in the study. The seeds were obtained from the Plant Genetic Resource Centre (PGRC) at Bunso, the Department of Crop Science, University of Ghana (UG), Legon and the Crops Research Institute (CRI) at Fumesua, near Kumasi. The 30 cultivars were as follows: 87/7, 87/1, 87/27, 87/147, 87/34, 87/49, 87/83, 87/157, 87/149, 87/30, 87/153, 96/046, 87/137, 96/129, BTB 96/091, OAA 96/30, BTB 96/054 (these are farmers' collections from PGRC); Caroni, Soronko, Gbeho, Kaase Market, 1977, 1239, Ayiyi, Asontem, Bengpla (these were collected from UG) and Asetenapa, Asontem1 and Adom (CRI); IT870-677-2 was collected from the International Institute of Tropical Agriculture, Ibadan, Nigeria.

Collections from UG and CRI were mostly released varieties with exception of Caroni, Kaase Market, 1977 and 1239 which are experimental materials used for student project in UG. These materials were planted in the University of Ghana experimental farm in the coastal savanna zone of Ghana. The pods were harvested at maturity and sun-dried. The dried seeds were homogenized using a blender. Three 100-mg of the homogenized seeds of each cultivar were weighed, wrapped in polyethylene films, packed into polyethylene irradiation capsules and heat-sealed.

Sample irradiation and elemental measurements

Samples were irradiated using the Ghana Research Reactor (GHARR-1) facility at the Ghana Atomic Energy Commission (GAEC), operating between 3–15 kW and at a thermal flux of 1–5.10^{11} $n \cdot cm^{-2} \cdot s^{-1}$. The irradiation was categorized according to half-lives of the elements of interest. Samples were transferred into the irradiation sites of the GHARR-1 reactor by means of pneumatic transfer system at a pressure of 65 psi. After irradiation, samples were allowed to cool down until activities reached acceptable handling levels. Each sample was placed on a detector for counting. Elemental measurements were done using a PC-based gamma-ray system as described by Serfor-Armah *et al.* (2001).

Results and discussion

A total of 14 elements, namely aluminium (Al), calcium (Ca), magnesium (Mg), vanadium (V), manganese (Mn), bromine (Br), chlorine (Cl), potassium (K), sodium (Na), zinc (Zn), copper (Cu), tantalum (Ta), silicon (Si) and indium (In) were detected in the seeds of the 32 cowpea cultivars analysed. These elements, their correspond-ing mean concentration and the standard deviation are given in Tables 1 and 2. Of the 14 elements detected five (Na, K, Mg, Ca and Cl) are classified as major elements, while nine (Mn, Zn, V, Cu, Si, Ta, In, Br and Al) are trace elements.

TABLE 1

Mean values (μg/g) of five major mineral elements of seeds of 30 cowpea cultivars

Accession	*Ca*	*K*	*Mg*	*Na*	*Cl*
OAA96/30	892.1±91.9	14710.0±235.4	2477.0±111.5	106.4±2.7	177.7±13.2
Kaase Market	640.5±74.3	13380.0±214.1	1798.0±104.3	107.8±2.8	167.1±13.2
Adom	1266.0±101.2	10000.0±190.0	1990.0±93.5	94.5±2.3	178.4±13.6
87/30	692.5±86.6	14840.0±237.4	2376±80.8	145.6±3.2	215.2±14.1
87/27	685.3± 85.0	14420.0±230.7	2208.0±79.5	136.0±3.1	228.0±14.1
87/153	733.6±77.0	12280.0±208.8	2358.0±113.2	129.5±3.0	161.7±12.4
87/149	976.1±97.7	13580.0±203.7	2699.0±124.2	116±4+2.7	234.0±17.9
87/34	1486.0±120.4	12340.0±210.0	5170.0±165.4	78.6±2.4	447.5±20.8
87/49	1550.0±133.3	12550.0±213.4	4633.0±152.9	113.9±2.9	489.5±20.8
87/147	862.2±84.5	12690.0±203.0	1960.5±72.5	104.7±2.5	149.5±12.0
96/046	757.2±84.0	12390.0±210.6	197.2±77.0	96.3±2.7	202.3±14.1
87/157	628.2±84.1	13990.0±223.8	2348.0±112.7	126.8±3.0	210.4±14.3
1977	1103.0±960.0	12520.0±200.3	2359.0±160.4	122.5±2.8	161.5±10.5
Asontem (1)	952.5±93.4	12470.0±212.0	1379.0±99.3	124.2±3.0	209.3±14.0
Ayiyi	2096.0±134.1	12710.0±203.4	2224.0±115.6	99.0±2.5	238.9±15.3
IT870-677-2	776.4±91.6	14390.0±230.2	2065.0±109.4	128.7±3.0	206.1±14.2
BTB96/054	1084.0±92.1	13060.0±209.0	1605.0±91.5	68.2±2.2	146.4±13.3
BTB96/091	792.8±83.2	12420.0±190.9	215.0±111.0	107.5±2.7	108.3±10.9
Caroni	1025.0±98.4	12110.0±205.9	690.0±65.5	90.7±2.5	187.1±13.3
87/83	nd	9372.0±178.1	2303.0±117.5	120.8±2.9	216.3±14.7
Soronko	nd	12310.0±197.0	1634.0±96.4	117.9±2.8	156.6±11.9
Gbeho	1013.0±94.2	16820.0±252.3	2621.0±120.6	101.8±2.8	249.7±15.0
87/1	740.0±84.8	11700.0±199.0	2067.0±117.8	118.8±2.7	180.6±12.9
87/137	778.7±90.0	8595.0±171.9	2198.0±107.7	142.7±3.1	162.9±12.7
87/7	1064.0±100.0	13060.0±209.0	1755.0±96.5	115.4±2.8	352.0±17.8
96/129	637.6±82.3	19050.0±266.7	1943.5±78.7	125.1±2.9	322.0±16.0
4557	705.3±81.1	13460.0±228.8	1828.0±100.5	128.9±30.0	132.2±11.0
Asontem	847.4±93.3	14033.0±210.5	1943.5±78.7	131.0±3.3	180.1±13.1
Bengkpla	743.3±89.2	12540.0±200.6	1828.0±100.5	112.7±2.8	215.7±16.5
1239	829.6±87.9	12600.0±201.6	2201.5±77.1	74.3±2.2	174.3±13.3

nd: below detection limit.

TABLE 2

Mean values (μg/g) of nine trace mineral elements of seeds of 30 cowpea cultivars

Accession	*Al*	*Cu*	*Mn*	*Zn*	*Ta*	*In*	*V*	*Si*	*Br*
OAA96/30	63.1±1.3	6.4±1.5	21.7±1.0	1030.0±211.2	nd	0.03±0.01	0.2±0.03	nd	nd
KaaseMarket	49.8±1.0	9.7±1.4	23.6±1.0	1501.0±220.7	73.9±21.2	0.02±0.01	nd	nd	nd
Adom	48.0±1.0	3.7±1.1	16.3±0.9	nd	91.7±22.5	0.02±0.01	0.1±0.03	nd	nd
87/30	45.1±1.0	6.8±1.3	15.0±0.8	1554.0±181.8	nd	nd	0.1±0.03	nd	nd
87/27	50.8±1.1	5.3±1.4	22.2±1.0	2082.0±262.8	nd	0.03±0.01	nd	nd	nd
87/153	64.7±1.2	3.3±1.1	24.5±0.8	nd	nd	0.05±0.01	0.2±0.03	nd	nd
87/149	46.8±1.0	11.5±1.5	23.0±1.1	nd	nd	0.07±0.01	0.1±0.03	nd	nd
87/34	90.3±1.5	12.3±2.1	57.5±1.6	nd	nd	nd	0.3±0.05	nd	2.6±0.7
87/49	92.7±1.5	7.3±1.7	53.2±1.6	nd	nd	0.06±0.01	nd	nd	nd

87/147	46.6±0.3	7.5±1.4	18.3±0.9	2040±255.0	nd	0.08±0.01	0.2±0.08	nd	nd
96/046	49.9±+1.0	4.9±1.4	16.7±0.8	nd	nd	0.05±0.01	nd	nd	nd
87/157	82.6±1.4	5.8±1.7	19.8±1.0	1771.0±258.6	nd	0.04±0.01	0.1±0.03	nd	nd
1977	54.3±1.1	nd	22.4±0.9	1799.0±229.1	nd	0.05±0.01	0.1±0.03	nd	nd
Asontem1	81.5±1.4	nd	10.0±1.0	nd	nd	0.04±0.01	0.2±0.03	nd	nd
Ayiyi	65.7±1.2	nd	19.6±1.1	nd	nd	0.05±0.01	nd	nd	nd
IT870-677-2	51.5±1.1	nd	30.6±1.1	nd	nd	nd	nd	nd	nd
BTB96/054	42.6±0.9	nd	16.8±0.9	nd	nd	0.04±0.01	0.1±0.02	nd	2.7±0.7
BTB96/091	52.2±1.0	nd	16.3±0.9	nd	nd	0.04±0.01	0.1±0.03	nd	nd
Caroni	46.1±1.0	5.4±1.3	19.6±1.0	nd	nd	0.04±0.01	0.1±0.03	nd	2.0±0.6
87/83	70.3±1.4	nd	15.2±0.9	nd	nd	0.04±0.01	0.2±0.04	nd	2.3±0.6
Soronko	39.2±0.9	nd	15.2±1.3	nd	nd	0.06±0.01	nd	nd	nd
Gbeho	53.3±1.1	nd	30.7±1.1	nd	nd	nd	0.1±0.04	nd	nd
87/1	49.9±1.3	nd	27.1±1.1	nd	nd	0.06±0.01	0.1±0.04	nd	nd
87/137	46.8±1.1	nd	24.6±1.1	nd	nd	0.04±0.01	nd	nd	nd
87/7	80.0±1.4	nd	19.8±1.0	nd	nd	nd	0.2±0.03	nd	nd
96/129	56.0±1.2	nd	22.3±1.0	nd	nd	0.04±0.01	nd	nd	nd
4557	52.6±1.1	nd	20.1±0.9	nd	nd	0.04±0.01	0.1±0.03	nd	3.0±1.0
Asontem	41.8±1.2	nd	14.5±0.8	nd	nd	0.07±0.01	nd	nd	nd
Benkpla	91.1±1.5	nd	24.9±1.0	2071.0±272.5	nd	0.05±0.01	nd	11750.0±0.01	4.2±1.0
1239	53.0±1.1	4.7±1.4	23.3±1.0	nd	nd	0.03±0.01	0.1±0.03	nd	nd

nd: below detection limit.

Variation in the major elements

The highest concentration of K was 19050.0 μg/g and was found in accession 96/129. The lowest concentration was 8595.0 μg/g and was found in accession 87/137. For Na the highest concentration was 192.0 μg/g and was found in accession 87/137. Calcium had the highest concentration of 2096.0 μg/g in Ayiyi, while the concentrations in accession 87/83 and Soronko were below detection limits. The highest concentration of Mg was 5170.0 μg/g and was detected in cultivar 87/34, while the lowest concentration of 155 μg/g was detected in cultivar 4557. The highest concentration of Cl was 489.5 μg/g and was detected in cultivar 87/49.

Variation in the trace elements

Bromine was detected only in the following six cultivars: 87/49, BTB 96/054, Caroni, 87/83, 4557 and Bengpla. In the remaining 26 cultivars the concentrations were below detection limits. The highest concentration of Al was 92.7 μg/g and was detected in cultivar 87/49. Concentrations of V in Kaase Market, 87/27, 897/49, 96/046, Ayiyi, IT870-677-2, Soronko, 87/137, 96/129, Asontem and Bengpla were below detection limits. The highest concentration of 0.3 μg/g was detected in 87/34. Zn was detected in only the following eight cultivars: OAA 96/30 (1030.0 μg/g), Kaase Market (1501.0 μg/g), Adom (1554.0 μg/g), 87/27 (2082.0 μg/g), 87/147 (2040.0 μg/g), 96/046 (1771.0 μg/g), 1977 (1749.0 μg/g) and Bengpla (2071.0 μg/g).

The highest concentration was detected in cultivar 87/27. Ta was detected in only Kaase Market (73.9 μg/g) and Adom (91.7 μg/g). The concentration level of In was below detectable limits in five of the cultivars. The highest concentration level of 0.1 μg/g was detected in 87/34. Mn was detected in all the 30 cultivars and the highest concentration level of 57.5 μg/g was detected in 87/34. Cu concentration in 15 cultivars was below detection limits. The highest concentration of 12.3 μg/g was detected in 87/34. Si was detected in cultivar 1239 at a concentration of 11750.0 μg/g. In the other 29 cultivars, Si concentration was below detection limit.

Correlation among elements

Correlation coefficient analysis was performed among the elements. Mg was positively correlated with Ca (r = 0.364, P < 0.048), Cl (r = 0.711, P < 0.000), Al (r = 0.490 P < 0.006), Cu (r = 0.448, P < 0.013) and Mn (r = 0.813, P < 0.000). Na was negatively correlated with Ca (r = -0.402, P = 0.028). Cl was positively correlated with Al (r = 0.657, P <0.000) and Mn (r = 0.749, P < 0.000). Al was positively correlated with Mn (r = 0.492, P < 0.006). Cu was positively correlated with Mn (r = 0.424, P < 0.02).

Several factors may account for the observed concentrations of the elements in the cowpea. These factors may include the concentration levels in the soil, translocation rates of the elements by the cultivars from the soil, and detection limits of the INAA technique. Cowpea, like other crops, depends on the soil for mineral elements needed for structural and catalytic functions (Purves, 1992). These minerals are taken up by means of active transport and, therefore, mineral levels in the plant tissue will, among other factors, be determined by the rate of active transport. In the present work, the 30 cowpea cultivars differed in their levels of the 14 mineral elements. This could be due to differences in their ability to take up mineral elements from the soil. Another possible reason is that the 30 cultivars may differ in their level of requirements for the 14 mineral elements.

The detection of five major elements considered essential to life and nine trace elements in the cowpea indicates that the crop contains a rich source of minerals. These elements form the main electrolyte of the human body, maintain tissue homeostasis and, at the same time, form the main structural components of bones and teeth (Linder, 1991). Danso *et al*. (2001) detected 10 elements in seven cassava cultivars while 14 elements were detected in cowpea in this present work. Therefore, cowpea is relatively richer in mineral elements than the seven cassava cultivars. Manganese, copper, tantalum and indium were absent in the seven cassava cultivars.

Conclusion

The variation found among the cowpea accessions shows that breeding for high mineral elements in the cowpea can be achieved by selection. This can be carried out by subjecting a large number of cowpea accessions to screening. From the results of this work the following accessions could be selected and incor-porated into a cowpea improvement programme: 96/129 (K), 87/137 (Na), Ayiyi (Ca), 87/34 (Mg, Mn and Cu), 87/49 (Cl and Al) and 87/27 (Zn). Generally cultivars of the farmer served as the best source of the minerals detected. The use of the INAA technique in this work has made the analysis of such elements as Zn, Al, Cu, Si, whose levels may be difficult to detect by the use of the Atomic Absorption Spectrophotometer analysis, possible.

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