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Full Length Research Paper

Essential elements content in core vegetables grown and consumed in Ghana by instrumental neutron activation analysis

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Food is the primary source of essential nutrients for man. Vegetables are essential part of the Ghanaian diet; therefore the nutritional status of vegetables is of importance. Vegetables that constitute an esse-ntial part of the Ghanaian diet have been analyzed for essential elements content (Ca, Mg, K, Co, Br, Mn, and Na) using Instrumental Neutron Activation Analysis (INAA). The purpose of the study was to design a nutrient database of the core vegetables grown and consumed in Ghana and in addition to ascertain the content of the essential elements in the vegetables. The accuracy of the method was verified by analysis of a compositionally appropriate reference material, IAEA -359 (CABBAGE). The results of the study revealed the presence of Br, Ca, Co, K, Mg, Mn, and Na in all the five vegetables studied. Ca, Mg, and K were present in the g/kg range in all five vegetables. The content of Na, Mn, Co and Br was in the mg/kg range in all five vegetables investigated.

Key words: Vegetables, Instrumental Neutron Activation Analysis, Elemental concentration, Ghana.

INTRODUCTION

Essential elements reach the human body through foods, ambient air, drinks, and occupational exposures. Human growth and metabolism rely on a balanced diet, which is composed of proteins, lipids, carbohydrates, vitamins and inorganic micronutrients. Although constituting a small fraction of the whole diet, inorganic micronutrients play an important role in various metabolic processes and their deficiency or excess may disturb the normal biochemical function of the body (Akhter et al., 2004). The essential elements in the body function as constituents of bones and teeth, as soluble salts which help to control the com-position of body fluids and cells and serve as essential adjuncts to many enzymes and other functional proteins (Dashti et al., 2004).

The elements considered essential are the major ele-ments (sodium, magnesium, phosphorus, chloride, potas-sium, and calcium) and the minor elements (chromium, manganese, iron, cobalt, copper, zinc, selenium, molybd-enum and iodine). In addition there are the newer trace elements, which are possibly essential; these are lithium, boron, fluorine, silicon, vanadium, nickel arsenic tin and lead (Crews, 1998).

The daily allowances or maximum tolerable intakes of trace elements entering humans through foodstuffs cre-ate the need for accurate and reliable determination of microgram and nanogram quantities of these elements in various foodstuffs (Dermelj et al., 1996).

Core foods are the foods most commonly consumed and consumed in the largest quantities by a population (Pennington, 2000).

Many people do not rely on food to supply the trace metal nutrients they consume. This is because they beli-eve that much of the food available in the marketplace has been depleted of nutrients. Others do so because they are convinced that the maintenance of good health and the need to ward off diseases require a higher intake of nutrients than can be met by consuming ordinary food. Food supplements are consumed to make up for this per-ceived shortfall. This state of affairs calls for the analysis of foodstuffs for their elemental concentrations, data acquired from such a study will help allay the fears of the public.

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The concentration of essential elements in foodstuffs of one region may vary from the other since food supplies are affected by various agricultural practices, type of soil, type of fertilizer and chemicals used, type of pesticides and herbicides sprayed. Besides these factors, intake of inorganic elements by the populace of any region may also depend on the geographical location of the area, climatic conditions, eating habits and socio-economic status (Waheed et al., 2002).

Two methods are generally considered applicable for estimating dietary exposure to essential trace elements: one is a biological monitoring programme that measures substances in body fluids and or tissue; the other is food monitoring programme (Coancher and Mes, 1993). Three different approaches can be applied to monitor exposure to essential micronutrient through food: selective analysis of individual foodstuffs, duplicate portion study and total diet study, which is also known as the market basket study (WHO, 1985; Nasreddine and Parent-Massin, 2002).

Though selective analysis of individual foodstuffs is labour intensive, it offers a number of advantages over the other methods. It prevents the 'dilution effect', which is the lack of detection of an analyte that may occur when the primary food source is mixed with other foods and analyzed as a food group composite. The analysis of individual core foods allows identification of the source of a nutrient. If a nutient is detected in a food group, it is not possible to determine which food contain the component without additional testing. In addition, the selective analysis of core foods allows for the development of a food composition database derived from analytical data. Data from analyses are more accurate than those taken from food composition tables where the values may be outdated or based on mere estimation (Pennington, 2000)

The essential elements in vegetables are present in trace and ultra-trace quantities. Hence, an analytical technique with sufficient sensitivity is required for the accurate determination of the essential elements in food samples. The major techniques employed are flame atomic absorption spectrometry (FAAS), graphite furnace atomic absorption spectrometry (GFAAS), inductively coupled plasma atomic emission spectrometry (ICP-AES), and inductively coupled plasma mass spectrometry (ICP-MS). Besides those mentioned above, other techniques such as differential pulse cathode stripping voltamperometry (DPCSV) and neutron activation analysis (NAA) have also been shown as excellent tools for trace and ultra-trace analysis (Inam and Somer, 2000; Szefer and Nriagu, 2007).

Neutron activation analysis is a less frequently used technique in the determination of essential elements in food samples because of the necessity of accessing a nuclear reactor. Despite this, NAA possesses a number of advantages and possibilities. Among the advantages is lack of necessity of chemical destruction (in the case of instrumental neutron activation analysis), appropriate accuracy, and possibility of simultaneous quantification of many elements in a small amount of sample (Żukowska and Biziuk, 2008).

Vegetable is an important and vital part of Ghanaian diet. In this work, five vegetables from various regions in Ghana have been studied for seven essential trace elements using multi-element, non-destructive and highly sensitive technique of instrumental neutron activation analysis (INAA). The selection of vegetables was based on importance in the Ghanaian diet and high consumption among the entire Ghanaian population. Data acquired from this study, will help create adequate and reliable nutritional information, as well as create awareness on the nutritional value of these vegetables

MATERIALS AND METHODS

Sample preparation

Five core vegetables were randomly purchased from large municipal markets in the Greater Accra region of Ghana. The quantity of vegetables purchased was normally a few kilograms from which sub-samples for analysis were taken. The vegetables purchased were: tomato (*Lycopersicom esculentum*), pepper (*Aframomum latifolium*), garden eggs (*Limnanthes sulphurea*), onion (*Allium cepa L.*), carrot (*Daucus Carota L.*).

Samples were placed into clean polyethylene containers and transported to the laboratory. At the laboratory, samples were thoroughly washed with ordinary water and then with doubly distilled water. From each market about ten sub-samples of each vegetable were selected and sliced into pieces using a carbon steel knife on a plastic slicing board. The sliced sub-samples were homogenized by thorough mixing. In the case of onions they were first peeled before been sliced into pieces.

Each sub-sample was further homogenized in a home-styled blender with stainless steel blades. Aliquots of each homogenized sample were frozen at -20°C and lyophilized (Christ Gamma 1-16) at - 30°C and 0.370 mbar. The lyophilized samples were milled in the vibratory disc mill (Retsch RS 100). The lyophilized homogenates obtained were stored in closed polyethylene bottles with screw caps and kept at - 20°C until analysis in order to prevent degradation of the sample. Drying by lyophilization was used because it ensures that the initial sample texture is preserved and in addition facilitates subsequent milling of samples (Hoenig, 2001).

Elemental analysis

Preparation of samples for neutron activation

Aliquots (about 200.00 mg) of the lyophilized homogenate were weighed into clean polyethylene foils, wrapped with forceps and the foil heat-sealed. Six replicates of each sample were prepared. Three replicate samples of compositionally appropriate reference material, International Atomic Energy Agency, IAEA-359 (Cabbage) were also prepared. The reference material was used as a comparator standard for gamma spectrum evaluation using the relative method of standardization for neutron activation analysis; and in addition to check the accuracy of the analytical method used.

Neutron activation of samples for medium-lived and long-lived radioisotopes

The reference material was ‘sandwiched’ between two aliquots of the same lyophilized homogenate and stacked together as close as possible. This was to ensure that samples and standards were

Table 1. Nuclear data used for determination of elemental concentrations (Filby et al., 1970).

Element	Reaction	Half-life	Energy (KeV)
K	^{41}K (n,) ^{42} K	12.36h	1524.7
Na	^{23}Na (n,) ^{24} Na	15.02h	1368.6; 2754.1
Br	^{81}Br (n,) ^{82} Br	35.3h	554.3; 776.5
Mg	^{26} Mg (n,) ^{27} Mg	9.45min	1014.4
Mn	^{55}Mn (n,) ^{56} Mn	2.58h	846.7; 1810.7; 2112
Co	^{51}Co (n,) ^{52} Co	3.76min	1434.1
Ca	^{48}Ca (n,) ^{49} Ca	8.7min	3084.4
Cl	^{37}Cl (n,) ^{38} Cl	37.3min	1642.4; 2167.5

activated under identical and same conditions as possible (any variation can remarkably affect the precision). The stacked samples and standard were then placed in the same polyethylene irradiation vial and irradiated for 1 and 6 h with thermal neutrons at a neutron flux of 5x 10^{11} neutrons cm $^{-2}$ s $^{-1}$, at the inner irradiation sites of the Ghana Research Reactor -1 facility, situated at the Ghana Atomic Energy Commission. The Ghana Research Reactor-1 is a 30 kW tank-in- pool miniature neutron source reactor (China Institute of Atomic Energy). It uses 90.2% enriched uranium (U- 235)–Aluminium alloy as fuel. It is cooled and moderated with light water and beryllium acts as reflectors (Akaho and Nyarko, 2002).

Measurement of induced activity in sample and standard followed immediately they were ejected from the reactor. At the end of the irradiation, samples and standards were allowed to 'cool' to enable non-analyte radioisotopes induced together with radioisotopes of interest and which half -life are shorter than that of the radioisotopes of interest to decay. In addition, to allow the activities induced in the samples to reach acceptable levels for handling (human health).

Neutron activation of samples for short-lived radioisotopes

Short-lived radioisotopes were induced in the samples and standards by 60 s irradiation with thermal neutrons in the pneumatic sample transfer facility of the research reactor. Samples and standards were stacked together as close as possible and placed in the same polyethylene irradiation capsule.

Measurement of induced activity in sample and standard followed immediately was ejected from the reactor. Samples were measured first followed by standards.

-activity measurement of samples and standards

Analysis of induced radioisotopes of interest was performed on a PC-based gamma- ray spectroscopy system. The spectroscopy system consists of a canberra high purity germanium (HPGe) N-type coaxial detector (model GR 2518-7500SL) with a resolution (FWHM) of 1.8 keV relative to the 1332.5 keV -energy line of ^{60}Co; a relative efficiency of 25%; and a peak-to-Compton ratio of 55.

Samples and standards were placed on the high purity germanium (HPGe) -ray detectors and the -activity of the induced radioisotopes measured at the same position and distance from detector. The measurement time for short-lived, medium-lived, and long-lived radioisotopes depended on the activity of the induced radionuclide. Samples were measured first followed by standards. A plexiglass source support was mounted on the detector in order to ensure easy and reproducible source positioning.

Evaluation of peak area of -spectrum

The peak area of the -spectrum for samples and standards were evaluated using the HPGe semiconductor detector - spectroscopy accumulation software, ORTEC MAESTRO-32. The areas under the peaks were integrated and converted into concentration using the relative method of standardization for neutron activation analysis. The nuclear reactions, half- lives and -energy of the radionuclides have been summarized in Table 1.

RESULTS AND DISCUSSION

Five core vegetables consisting of tomato, garden egg, onion, pepper and carrot were analyzed for essential elements of nutritional significance using instrumental neutron activation analysis (INAA). The concentrations were calculated on dry weight basis and each concentration is an average of six individual determinations. The irradiation scheme employed prevented any serious elemental interference.

Elemental concentrations in vegetables

The results for the analysis of the essential elements in the five vegetables, and the ranges are presented on Tables 2 and 3.

Calcium content in the vegetables

The concentration of calcium in tomato was found to vary from 0.002 to 0.24 g/kg with a mean of 0.17 g/kg. The concentration of calcium in garden egg varied from 0.01 to 0.16 g/kg with a mean of 0.10 g/kg. The content of calcium in onion was found to be 0.60 g/kg and varied from 0.44 to 0.88 g/kg. For pepper, the calcium content was in the range of 0.09 to 0.84 with a mean of 0.26 g/kg. Calcium in carrots was found to vary from 0.26 to 0.53 g/kg with a mean of 0.37 g/kg.

The results from the study show high calcium content in onion (0.60 g kg^{-1}); the mean content in garden egg was the lowest (0.10 g/kg). However, some of the concentrations of calcium in garden eggs overlapped with the contents in other vegetables. Carrots and pepper contains appreciable levels of calcium. Even though plant foods like vegetables can be excellent sources of several minerals, the mineral content of plant food can vary dramatically depending on the minerals in the soil where the plants are cultivated. The maturity level of a vegetable can also influence its mineral content. These factors could have accounted for the wide variation in the content of calcium in the vegetables. Other soil factors which may have influenced the variations are pH and salinity. Calcium acts as the main structural element of bones and teeth in humans. Calcium is also essential for the formation of fibrinogen which is vital for blood clotting. Low Ca intake causes deficiency in the body leading to

Table 2. Na, Br, Co and Mn contents (mg kg^{-1}) in the vegetables.

	Content of essential elements in vegetables (mg kg^{-1})				
Mineral	**Tomato**	**Garden egg**	**Onion**	**Pepper**	**Carrot**
Na	323.8± 22.5	46.8 ± 1.9	379.9 ± 9.1	57.3 ± 3.3	981.1 ± 26.2
	(44.20 – 1400)	(24.49 - 83.30)	(53.70 – 715.40)	(25.80 - 92.60)	(104 – 2500)
Mn	37.02 ± 2.58	21.50 ± 1.34	90.14 ± 4.01	19.07 ± 1.73	36.12 ± 2.55
	(27.23 - 65.10)	(12.50 - 27.32)	(43.74 - 169.70)	(16.10 - 22.50)	(29.63 - 44.14)
Br	23.47 ± 1.91	36.78 ± 2.06	89.65 ± 4.14	14.89 ± 1.34	17.85 ± 2.21
	(15.26 - 37-93)	(22.40 - 47.50)	(70.20 - 142.60)	(7.56 - 29.10)	(12.97 - 29.70)
Co	5.36 ± 0.28	5.65 ± 0.35	4.96 ± 0.36	4.36 ± 0.30	7.19 ± 0.37
	(5.08 - 6.30)	(4.68 - 7.00)	(4.32 - 6.43)	(3.62 - 6.10)	(6.40 - 8.10)

Data are expressed as mean ± standard deviation on a dry weight basis (Range).

Table 3. Ca, Mg, and K contents (g kg^{-1}) in the vegetables.

	Essential elements content (g kg^{-1}) in the vegetables				
Mineral	**Tomato**	**Garden egg**	**Onion**	**Pepper**	**Carrot**
Ca	0.17 ± 0.01	0.10 ± 0.01	0.60 ± 0.02	0.26 ± 0.01	0.37 ± 0.01
	(0.01 - 0.16)	(0.44 - 0.88)	(0.09 - 0.84)	(0.26 - 0.53)	(0.002 -0.24)
Mg	0.16 ± 0.02	0.15 ± 0.01	0.59 ± 0.03	0.13 ± 0.01	0.16 ± 0.02
	(0.14 - 0.16)	(0.53 - 0.77)	(0.09 - 0.21)	(0.04 - 0.30)	(0.10 - 0.25)
K	2.84 ± 0.06	3.79 ± 0.07	2.25 ± 0.07	1.22 ± 0.03	1.75 ± 0.05
	(1.44 - 10.70)	(1.74 - 2.94)	(0.75 - 2.01)	(0.74 - 3.07)	(0.28 - 4.29)

Data are expressed as mean ± standard deviation on a dry weight basis (Range).

osteoporosis. Calcium deficiency may also cause rickets in children. The functions of calcium in the human system demand sufficient intake of this mineral.

The study revealed that onions, pepper, carrots grown in Ghana contain appreciably high content of calcium. Though the calcium content in tomato and garden egg are relatively low, these vegetables are good sources of calcium.

Analysis of induced radioisotopes of interest was performed on a PC-based gamma-ray spectroscopy system. The spectroscopy system consists of a canberra high purity germanium (HPGe) N-type coaxial detector (model GR 2518- 7500SL) with a resolution (FWHM) of 1.8 keV relative to the 1332.5 keV -energy line of ^{60}Co; a relative efficiency of 25%; and a peak-to-Compton ratio of 55.

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The results from the study show high calcium content in onion (0.60 g kg^{-1}); the mean content in garden egg was the lowest (0.10 g/kg). However, some of the concentrations of calcium in garden eggs overlapped with the contents in other vegetables. Carrots and pepper contains appreciable levels of calcium. Even though plant foods like vegetables can be excellent sources of several minerals, the mineral content of plant food can vary dramatically depending on the minerals in the soil where the plants are cultivated. The maturity level of a vegetable can also influence its mineral content. These factors could have accounted for the wide variation in the content of calcium in the vegetables. Other soil factors which may have influenced the variations are pH and salinity. Calcium acts as the main structural element of bones and teeth in humans. Calcium is also essential for the formation of fibrinogen which is vital for blood clotting. Low Ca intake causes deficiency in the body leading to osteoporosis. Calcium deficiency may also cause rickets in children. The functions of calcium in the human system demand sufficient intake of this mineral. The study revealed that onions, pepper, carrots grown in Ghana contain appreciably high content of calcium. Though the calcium content in tomato and garden egg are relatively low, these vegetables are good sources of calcium.

Magnesium content in the vegetables

Magnesium is an essential element known to be vital for the activity of a number of human enzymes particularly those that are involved with the oxidative phosphorylation. Its chief function in the body includes bone mineralization, building of proteins, and transmission of nerve impulse and maintenance of teeth. Magnesium deficiency results in renal failure, acute diarrhea and protein–caloric malnutrition. These deficiencies may then cause irritability, muscular tremor, hallucination and depression.

Mean magnesium contents in the vegetables were found to be nearly the same: 0.16 g/kg in tomato, 0.15 g/kg in garden egg, 0.13 g/kg in pepper and 0.16 g/kg in carrots. The content of 0.59 g/kg found in onion varied sharply from the content in the other vegetables. The similar content of magnesium in tomato, pepper, garden egg and carrot could be that these vegetables were grown in the same geographical area and therefore there is no marked variation in the mineral composition of the soil in which the vegetables were grown. The high content of magnesium in onion may be due to high uptake of magnesium from the soil by onion, assuming it was also grown in the same geographical area as the other vegetables were grown. The onion might also have been grown in a different geographical area with high magnesium content in the soil. It was not possible to establish where the vegetables were grown as the traders were either not certain about which geographical area the vegetables were grown, or gave conflicting prediction as to the exact geographical areas the vegetables were grown. In addition, the conditions which the vegetables were subjected to before being carted to the marketing centers could not be established. These factors may have accounted for the differences in levels of the essential elements in the vegetables.

Sodium content in the vegetables

Sodium content in the vegetables from the markets were in the ranges of 44.20–1400 for tomato, 24.49-83.30 for garden egg, 53.70–715.40 for onion, 25.80-92.60 for pepper and 104 – 2500 for carrots. All values are in mg kg^{-1}. There was no significant variation in the sodium contents in garden egg and onion. This could be attributed to the sodium content in the soils in which the garden egg and onion were grown, even though they might not have come from the same geographical location. Variation in the sodium content in onion and tomato were significant. The variations in the content of sodium in onion, carrots and tomato may be attributed to factors such as the preferential uptake of sodium by these vegetables, which can also be influenced by the age of the plant. Ambient climatic conditions and mineral composition of the soil in which the vegetables were grown as well as the type of fertilizer and pesticides sprayed might have influenced the concentration of the elements obtained.

Na is a major physiological element and a primary extra – cellular cation in humans. Na together with Cl and K are electrolytes that maintain normal fluid balance inside and outside cells and a proper balance of acid and bases in the body. Deficiency of this element may result in muscle cramp and hypertension.

Potassium content in the vegetables

Potassium concentrations in all the five vegetables studied were very high. Potassium is a macronutrient and

Table 4. Concentrations (g g^{-1}) of some analyzed elements in certified reference material.

Element	Present study [a]	Reported	Precision (%)	Accuracy (%)
Ca	19200± 265 (5)	18500± 510	1.38	3.78
K	31600± 344 (4)	32500± 690	1.09	-2.77
Mg	2130± 17 (6)	2160 ± 50	0.80	-1.39
Mn	32.4 ± 0.3 (6)	31.9± 0.6	0.93	1.57
Na	590±9(4)	580± 13	1.53	1.72

[a]Average ± standard deviation (number of determinations).

a major intracellular cation in the human body. Its deficiency causes nerve irritability, cardiac and mental disorder, muscular weakness and paralysis. Potassium also facilitates the transmission of nerve impulses.

The concentration of potassium in tomato was found to vary from 0.28 to 4.29 g/kg with a mean of 2.84 g/kg. The concentration of potassium in garden egg varied from 1.44 to 10.70 g/kg with a mean of 3.79 g/kg. The content of potassium in onion was found to be 2.25 g/kg and varied from 1.74 to 2.94 g/kg. For pepper, the potassium content was in the range of 0.75 to 2.01 g/kg with a mean of 1.22 g/kg. Potassium in carrots was found to vary from 0.74 to 3.07 g/kg with a mean of 1.75 g/kg. The results from the study show high potassium content in garden egg (3.79 g kg^{-1}); the mean content in pepper was the lowest (1.22 g/kg). However, some of the contents of potassium in garden eggs overlapped with the contents in other vegetables. The marked variation in the concentration of potassium in the vegetables might be due to the levels of potassium in the soils in which the vegetables were cultivated. In addition, the nutrient levels in soils vary geographically and the vegetables might have been brought to the market centre from different geographical locations. The high potassium content in garden egg may be attributed to the preferential uptake of potassium from the soil by the garden egg plant. In addition, the content may have been influenced by genetic diversity.

Amendment of the soil by the application of top dressings and agrochemicals could also have had a significant influence on the potassium content in the soil, thereby affecting the content in the vegetables.

Manganese content in the vegetables

Manganese content in the vegetables from the markets was in the ranges of 27.23-65.10 for tomato, 12.50-27.32 for garden egg, 43.74-169.70 for onion, 16.10-22.50 for pepper, and 29.63- 44.14 for carrots. All values are in mg kg^{-1}. There was no significant variation in the manganese content in the vegetables. The content of manganese recorded may have been influenced by the insignificant variation in the content of manganese in the soils in which the vegetables were grown. The uptake of manganese from the soil by these vegetables could have been the same or nearly the same.

Manganese is a key cofactor in reactions of key importance in the human body. It is involved in energy metabolism and urea formation. Manganese is a component of the antioxidant enzyme superoxide dismutase.

Bromine and cobalt content in the vegetables

The results for the cobalt content in the vegetables did not show any significant variation. Cobalt content in the vegetables from the markets were in the ranges of 5.08-6.30 for tomato, 4.68-7.00 for garden egg, 4.32-6.43 for onion, 3.62-6.10 for pepper, and 6.40-8.10 for carrots. All values are in mg kg^{-1}. This may have been influenced by the insignificant variation in the cobalt content in the soil, irrespective of the geographical area.

The content of bromine in the vegetables did not also show any significant variation. However, the bromine content in onion was slightly higher than the content in other vegetables. This may be due to preferential uptake of bromine from the soil by the plant. Bromine in onion varied from 70.20 to 142.60 mg/kg, with a mean of 89.65 mg/kg. The bromine content in tomato was found to vary from 15.26 to 37.93 mg/kg; for garden egg, it varied from 22.40 to 47.50 mg/kg; in pepper it varied from 7.56 to 29.10 mg/kg; and a variation of 12.97 to 29.70 mg/kg in carrot. The reason for the insignificant variation may also be due minimal variation in the bromine content in the soil irrespective of the geographical area.

Quality assessment

The precision and accuracy of the method was evaluated by repeated analyses of a compositionally appropriate certified reference material, IAEA -359 (CABBAGE) under the same experimental conditions. The detailed results of the assessment are presented in Table 4.

The precision of the measurement, in terms of relative standard deviation is 1.38, 1.09, 0.80, 0.93, and 1.53% for Ca, K, Mg, Mn, and Na, respectively. The accuracy of the measurements, in terms of the relative deviation from the IAEA certified values are 3.78% for Ca; -2.77% for K; -1.39% for Mg; 1.57% for Mn; and, 1.72% for Na. There is generally good agreement between the IAEA certified values and the values obtained in the present study.

The equations used for the calculation of precision and accuracy are:

$$R_{SD} = (\sigma / \bar{x}) * 100 \qquad (1)$$

where, R_{SD} is the relative standard deviation; is the standard deviation; and, $\bar{x}$ is the arithmetic mean of 8 independent determinations.

$$R_D = (x - x_c) / x_c \qquad (2)$$

where, R_D is the relative deviation; x is the measured value in the present study and x_c is the NIST certified value.

Comparison of essential trace element content with literature data

The mean calcium content in the Ghanaian vegetables was remarkably high ranging from 0.10 g/kg (*Limnanthes sulphurea*) to 0.60 g/kg (*Allium cepa L*). Comparison of these values with literature data for traditional South African leafy vegetables shows that the calcium content in the leafy vegetables were significantly higher, >1000 mg/100 g for all species of South African leafy vegetables analyzed except *Galinsoga parviflora* (162 mg/100 g) and *Ceratotheca triloba* (705 mg/100 g) (Odhav et al., 2007).

Literature data for South African leafy vegetables show substantial quantities of sodium, 1460 mg/100 g (*Oxygonum sinuatum)*. *Centella asiatica* contained the lowest amount of 16 mg/100 g (Odhav et al., 2007). The sodium content in the Ghanaian vegetables was remarkably low, ranging from 46.8 mg/kg (*Limnanthes sulphurea*) to 981.1 mg/kg (*Daucus Carota L*).

The magnesium content in the Ghanaian vegetables studied ranges from 0.13 g/kg (*Aframomum latifolium*) to 0.59 g/kg (*Allium cepa L*). The values from this study were slightly lower than literature values for the traditional South African leafy vegetables, 193 mg/100 g *(Wahlenbergia. undulata)* to 1409 mg/100 g (*Justicia flava*) (Odhav et al., 2007).

Manganese content in the Ghanaian vegetables ranges from 19.07 mg/kg (*Aframomum latifolium*) to 90.14 mg/kg (*Allium cepa L*). Comparison of these values with literature data for traditional South African leafy vegetables shows that the manganese content in the leafy vegetables were significantly higher, ranging from 2 mg/100 g (*Physalis*. *viscosa*) to 82 mg/100 g (*Amaranthus. dubius*) (Odhav et al., 2007).

Conclusion

Vegetables that constitute an essential part of Ghanaian diet were analyzed for elements of nutritional significance using INAA. Generally, the results established that Ca, Mg, and K were present in high concentration in all the five vegetables studied, while Br, Co, Mn, and Na were at appreciably levels. The results of this study indicate that the vegetables studied are well endowed with essential nutrients required for human consumption. The data should be used to promote the nutritional values of these vegetables among the Ghanaian population. In addition, the data generated will be used to build a nutrient database for vegetables grown and consumed in Ghana. From the study, tomatoes, garden eggs, onions, pepper and carrots are good sources of K, Mg, Ca, Na, Br, Co and Mn.

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