Available online at www.elixirpublishers.com (Elixir International Journal)

Food Science

Elixir Food Science 53 (2012) 12169-12174

ISSN: 2229-712X

Levels of Some Essential Elements in Edible Plantain (Musa Spp) Species from Bibiani Mining Area

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ARTICLE INFO

Article history:

Received: 5 November 2012;
Received in revised form:
22 December 2012;
Accepted: 26 December 2012;

Keywords

Bibiani,
Plantain,
Levels,
Essential elements,
INAA.

ABSTRACT

Nine plantain samples from some communities in the Bibiani mining town and surrounding towns/villages, Abrofrem, Akwawuakrom, Beposo, Besie, Fahiakorbor, Kofikrom, Hwenampori and Old Town – all in the Bibiani-Anhwiaso-Bekwai District – have been analysed using Instrumental Neutron Activation Analysis (INAA) for their levels of the essential elements, Ca, Cl, Cu, K, Mg, Mn, Na and Zn. The aim of the study was to determine the levels of the above essential elements in the plantain samples and also to establish whether the mining activities have had any impact on the levels measured. The concentrations of Ca, Cl, K, Mg and Na referred to as major nutrients measured were in the ranges; 495 – 1895 mg/kg for Ca, 1076 – 3019 mg/kg for Cl, 1800 – 17000 mg/kg for K, 946 – 1337 mg/kg for Mg, and 42.34 – 83.20 mg/kg for Na. The micro/trace elements measured in the samples were in the ranges, 2.55 – 25.44 mg/kg for Cu; 7.40 – 17.20 mg/kg for Mn and 8.25 – 67.96 mg/kg for Zn. The results supported the claim that plantain contains high levels of K and low levels of Na. However, with regard to the RDA/AI values of the various nutrient elements, it could be said that plantain is relatively richer in Mn, followed by Cu and Mg than K. This was due to the fact that relatively lower amount of plantain is required to meet the RDA/AI values of those elements than K. The levels of the nutrient elements measured in the plantain samples did not give any indication of impact of mining activities which could have resulted in loss of soil fertility since the results obtained in this work compared favourably with the results obtained in a similar study conducted by Danso *et al* (2006) in a non mining area. The only difference observed in the results obtained in this work from that of Danso *et al* (2006) was with the levels of Mg and Mn. The levels of Mg and Mn measured in this work were however, consistent with the geology of the area as well as their respective RDA/AI values.

Introduction

Minerals nutrients are inorganic elements that originate from the earth and cannot be made in the body (IFA, 2011). They are essential elements because they play important roles in various biochemical processes in the body necessary to sustain life and maintain optimal health (Ozcan, 2003). Since they cannot be manufactured by the body they must be present in food or food supplements in order to meet the body requirement for normal growth and other vital roles they play in the body. The elements, As, Ca, Co, Cr Cu, Cl, F, Fe, I, K, Mg, Mn, Mo, Na, Ni, P, Se, Si, Sn, V and Zn are considered essential elements (Danso *et al*, 2001). Vegetables, fruits, and some food crops including plantain can serve as a good source of minerals when consumed.

Plantain, known scientifically as *Musa ssp*, is a food crop that serves as a major staple food, not only in Ghana, but in Africa and other parts of the world. Plantain is widely cultivated in most African countries (including Ghana, Nigeria, La Cote D'ivoire, Cameroun, Uganda etc.) and also in Asia and Latin American countries (Lescot & Ganry, 2008). In these countries, plantation production is not only for consumption locally but also for export. Ghana has been the largest producer of plantain in West and Central Africa since 2001 (AA, 2011). In the year 2001, plantain contributed 13.1% of Ghana's Agricultural Gross Domestic Product out of which 101.8 kg, representing 90%, was consumed locally since it (plantain) ranked very high in food preference (AA, 2011).

Plantain contains vitamins A B1, B2, B3, B6, C, and minerals such as potassium hence, very rich nutritionally. It is low in fat and for that matter, recommended for the obese. Also, it has low sodium and cholesterol content and that makes it useful in managing high blood pressure and heart disease conditions in patients. Furthermore, it contains less toxic and anti-nutrient substances such as cyanogenic glucosides in plantain and glycoalkaloids in potatoes (Sharrock & Lusty, 1999) making it relatively safer for consumption.

Some studies have already been done to determine the nutritional value of various plantain species and other food crops like cassava and cocoyam in many parts of the country (Danso *et al* 2001, Danso *et al*, 2006, Dzomeku *et al*, 2008). In these studies, various parameters of the food crops were studied. Some of the parameters studied included mineral nutrients, moisture,

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ash, crude fat, crude protein and crude fibre. Danso *et al* (2006) studied the levels of nutrients elements in the pulps as well as the peels of various edible plantain species in Ghana. However, their studies did not account for the roles, if any, the sources of the plantain samples might have played to influence the levels of the nutrient elements measured.

In this study, the nutrient element levels of plantain in a particular locality, Bibiani (a mining town) and its environs were looked at, vis-à-vis the mining activities that go on in the area. This was against the backdrop that among other factors, the quality of the soil on which it was cultivated, is one of the important factors that determine the nutritional value of any food crop (Sharrock & Lusty, 1999). Furthermore, soil fertility is severely affected by deforestation and land degradation which are both known to be some of the negative impacts of mining. These two factors are responsible for loss of large tracks of arable land for crop production. Affected farmers have no choice other than to farm these lands that have lost their fertilities. In situations where the farmers are not able to afford fertilizers, the yields of the crops are affected drastically, and this might as well affect the nutritional value of the crops.

We embarked on this study to determine the levels of nutrient element in plantain samples from the Bibiani mining area and to also ascertain whether the levels of the nutrient elements have been affected by the mining situation. We studied plantain because it forms an important part of the diet of many Ghanaians and moreover, it is produced in large quantities for export.

Materials and Methods

Study Area. Bibiani, the capital of Bibiani-Anhwiaso-Bekwai District, and surrounding towns/ villages, Abrofrem, Akwawuakrom, Beposo, Besie, Fahiakorbor, Hwenampori, and Kofikrom were studied. A detail description of the study area, a map showing the study area as well as a geological map of the area are available (BABDA, 2006; Quarshie *et al*, 2011).

Sampling and Sample preparation. Nine (9) plantain samples were taken from farms/gardens in nine towns/villages in the Bibiani area. The plantain samples were collected from Old Town, coded as OTP1 and OTP2; Hwenampori (HP1), Beposo (BPP1), Akwawuakrom (AP1), Kofikrom (KP1), Fahiakorbor (FP1), Besie (BSP1) and Abrofrem (ABP1).

The samples were washed with DDW to remove soil particles and subsequently packed into polyethylene bag. The bagged samples were labeled, kept at a temperature below 0°C in with ice cubes in an ice chest and transported to the laboratory. Each of the plantain, samples was, again, washed (separately) with DDW (Danso *et al*, 2001) and then peeled on a pre-cleaned plastic chopping board using a stainless steel kitchen knife while wearing rubber gloves. The peeled samples (the pulp) were chopped into smaller pieces (to facilitate drying), collected into pre-cleaned labeled Petri dishes and kept frozen in a freezer. The frozen samples were freeze-dried in the Christ Freeze Dryer for 4 days. The dried samples were then kept in labeled pre-cleaned polyethylene bags and subsequently milled using a commercial blender into powdery form.

Eight replicates (200 mg) of each of the milled samples were weighed and packaged. Four of the eight replicates were used for the determination of short-lived nuclides and the other four for the determination of the medium-lived nuclides.

Irradiation, counting and analysis. Irradiations were performed using the Ghana Research Reactor-1 (GHARR-1) facility at Ghana Atomic Energy Commission, Kwabenya. GHARR-1 is a miniature neutron source reactor (MNSR). Thermal neutrons were used to irradiate all the samples and the reference materials.

The samples were sent into the inner irradiation sites of the reactor by means of a pneumatic transfer system operating at 448 kpa. At the inner irradiation site the samples were irradiated with a thermal flux of $5 \times 10^{11} ncm^{-2}s^{-1}$ while the reactor operated at 15kW (Adotey, 2003; Serfor-Armah, 2006). Different timing schemes were used for the irradiation, decay and counting of the short and medium-lived radionuclides. The irradiation scheme t_i: t_d: t_c = 0.5 - 2: 1: 10 mins was used for the short-lived whilst t_i: t_d: t_c = 1: 24 - 48: 0.5 hrs was used for the medium-lived radionuclides (Serfor-Armah, 2006).

The timing for the various irradiation schemes were chosen based on the matrix being dealt with (whether geological or biological matrix), the half-lives of the radionuclides to be determined, safety (to avoid exposure to high doses of radiation during handling) and optimization of counts and at the same time reducing pulse pile up (dead time). Also, the timing schemes were chosen with regard to the time available for analysis as well as to reduce interference from other radionuclides present in the sample.

The samples were counted on a computer-based gamma-ray spectroscopy system which consists of an N-type High Purity Germanium (HPGe) detector model GR 2518, a High Voltage Power Supply (model 13103), and a Spectroscopy Amplifier (model 2020, Canberra Industries Incorporated). ACCUSPEC multi-channel analyzer (MCA) emulation software card and a microcomputer for data acquisition, evaluation and analysis were also used. Both quantitative and qualitative analyses were done using the Gamma Spectrum Analysis Software, MAESTRO 32 (Adotey, 2003).

Results and Discussions

The reference material, IAEA 336 (Lichen) was analyzed for the concentration of the elements, Cl, Cu, K, Mn, Na and Zn. The results obtained are presented alongside the recommended values in the table 1 below. The results obtained were in close agreement with the recommended values suggesting that the analytical technique used for this work was reliable (Table 1).

The essential/nutrient elements measured in the plantain samples in this work fall under two sub groups: Minerals/major nutrients, consisting of Ca, Cl, K, Mg and Na; and micro/trace elements made up of Cu, Mn, and Zn (IFA, 2011). The major nutrients are found in a typical adult human body in quantities above 5g and over 100mg are required by a typical adult human body per day. Micro or trace elements on the other hand are found in a typical adult human body in quantities below 5g and less than 100mg are required by a typical adult human body per day (IFA, 2011).

Major elements: The concentrations of the major nutrients measured were in the ranges; 495 – 1895 mg/kg for Ca, 1076 – 3019 mg/kg for Cl, 1800 – 17000 mg/kg for K, 946 – 1337 mg/kg for Mg, and 42.34 – 83.20 mg/kg for Na (Tables 2a & b). Potassium recorded the highest concentration among all the major nutrients whilst sodium recorded the lowest concentration as was measured in the samples coded HP. The high levels of Ca, K and Mg are not unexpected because these elements together with Na are major elements associated with the geology of the area (Quarshie *et al*, 2011). The low levels of Na are however, unexpected; and may suggest that plantain poorly bioaccumulates Na. The levels corroborate earlier reports that plantain is very rich in potassium and low in sodium.

Table 1: Comparison of concentrations of elements measured in IAEA 336 (Lichen) in this work with the recommended values.

	IAEA 336 (Lichen)	
Elements	**This work**	**Recommended value**
Cl%	0.19 ± 0.03	0.19 ± 0.03
Cu	3.54 ± 0.3	3.60 ± 0.5
K%	0.18 ± 0.02	0.18 ± 0.02
Mn	66 ± 5	63 ± 7
Na%	0.03±0.002	0.03 ±0.004
Zn	30.6 ± 3.6	30.4 ± 3.4

Table 2a: Average concentrations of elements in plantain samples with standard deviations (mg/kg, unless indicated otherwise)

Elements	ABP	AP	BPP	BSP	FP
Ca	648 ± 1.94	690 ± 2.07	495.73 ± 1.49	769 ± 2.31	881 ± 2.64
Cl	1570 ± 4.71	1076 ± 3.23	2469 ± 7.41	1369 ± 4.11	1176 ± 3.53
Cu	5.43 ± 0.16	2.55 ± 0.08	12.37 ± 0.37	6.34 ± 0.19	15.02 ± 0.45
K (x 10^4)	1.50 ±0.02	1.36 ± 0.025	0.18 ± 0.003	1.41 ± 0.025	1.62 ± 0.02
Mg	1337 ± 4.01	980 ± 2.94	946 ± 2.84	1051 ± 3.15	969 ± 2.91
Mn	9.50 ± 0.29	8.02 ± 0.24	7.40 ± 0.22	11.24 ± 0.34	17.20 ± 0.52
Na	83.20 ± 0.25	78.45 ± 0.24	54.11 ± 0.16	60.60 ± 0.18	54.11 ± 0.16
Zn	44.78 ± 0.34	26.58 ± 0.08	<0.01*	44.08 ± 0.13	67.96 ± 0.20
Moisture (%)	66	58	50	61	63

* Detection limit

Table 2b: Average concentrations of elements in plantain samples with standard deviations (mg/kg, unless indicated otherwise) and RDA/AI values

Elements	HP (Control)	KP	OTP1	OTP2	RDA/AI (mg/day)
Ca	703 ± 2.11	591 ± 1.77	547 ± 1.64	1895 ± 5.69	1300 (AI^y)
Cl	3019 ± 9.06	2271 ± 6.81	2376 ± 7.13	2238 ± 6.71	2300 (AI^y)
Cu	11.99 ± 0.04	4.63 ± 0.02	25.44 ± 0.08	5.45 ± 0.02	0.89 (RDA^y)
K (x 10^4)	1.70 ± 0.03	1.59 ± 0.02	1.59 ± 0.02	1.38 ± 0.02	4700 (AI y)
Mg	1092 ± 3.28	957 ± 2.87	1272 ± 3.82	773 ± 2.32	410^a, 360^b (RDA^y)
Mn	8.50 ± 0.03	7.71 ± 0.02	8.28 ± 0.02	7.84 ± 0.02	2.2^a, 1.6^b (AI^y)
Na	42.34 ± 0.13	66.08 ± 0.20	48.02 ± 0.14	75.06 ± 0.23	1500 (AI^y)
Zn	<0.01*	53.72 ± 0.16	<0.01*	8.25 ± 0.02	11^a, 9^b (RDA^y)
Moisture (%)	58	55	63	48	

* Detection limit

RDA/AI: Recommended Dietary Allowance/Adequate Intake

(RDA^y)/(AI^y): RDA/AI for adults 18 and above

a RDA/AI values for males 18 and above

b RDA/AI values for females 18 and above

It also justifies the recommendation of plantain for people suffering from high blood pressure as a means of managing their condition (Sharrock & Lusty, 1999). Chloride recorded the next highest concentration after potassium with the highest concentration measured being 3019 mg/kg (as measured in sample coded HP).

Micro/trace elements: The micro/trace elements measured in the samples were in the ranges, 2.55 – 25.44 mg/kg for Cu; 7.40 – 17.20 mg/kg for Mn and 8.25 – 67.96 mg/kg for Zn. However, the concentrations of Zn in the samples coded BPP, HP and OTP1 were below the 0.01 mg/kg detection limit of Zn. This might be as a result of poor absorption of Zn by plants because, according to Sandstead & Au (2007), zinc deficiency in plants is a worldwide problem.

Sample HP recorded the highest levels for Cl and K among all the plantain samples analysed, whilst FP recorded the highest levels of Mn and Zn. On the other hand, OTP1, OTP2 and ABP recorded the highest levels for Cu, Ca and Na respectively. Sample HP was from a household garden fertilized with domestic waste hence, nutrients supplied by the domestic waste might account for the levels of Ca and Cl measured. Sample coded FP was from a farming village known as Fahiakorbor. The results may suggest that the soil in the area is not adversely impacted by activities such as mining which could have resulted in loss of its fertility. It could also imply that the farmers in the community engage in some sort of fertilizer application on their farms. The samples OTP1 and OTP2, by virtue of their proximity to the Bibiani mine, were expected to experience the worse of the impacts of mining activities but this did not reflect in the levels of Cu and Ca, probably because of fertilization with household waste as was the case in most household gardens.

Sodium potassium and chloride are the main ions in the body fluid. Whilst sodium and chloride are found in the extra cellular fluid, potassium is the main base ion for intracellular fluid of the body (Sheng, 2000; Rose *et al*, 2000). These three ions together are responsible for acid base balance and maintenance of osmotic pressure of body fluids. Sodium and potassium also play important roles in transmission of nerve impulses and muscle contractions. Chloride is the chief anion of gastric juice (HCl) and thus contributes to digestion and waste elimination (Murray *et al*, 2000). Calcium is the most abundant mineral in the body and is the primary structural constituent of teeth and bone. It also plays important roles in regulation of nerve and muscle function, activates enzymes and also helps in blood and milk coagulation (NRC, 1989; Arnaud & Sanchez, 1990; Wood, 2000). Magnesium is the second most abundant cation found within the cells of the body (SCF, 1993; Saris *et al*, 2000). In addition to serving as a cofactor for over 300 enzymatic reactions and being involved in the functions of the enzymes of lipid protein and nucleic acid metabolism, magnesium also works with calcium in regulating nerve and muscle activities and also serves as constituent of bones and teeth (SCF, 1993; Saris *et al*, 2000).

Copper is an essential micro nutrient that plays vital roles in both the circulatory and the nervous system, not to mention the fact that it is a constituent of many enzymes including, amine oxidase, ascorbic acid oxidase, catalase, cytochrome c oxidase, cytosolic superoxidase dismutase and peroxidase, being responsible for their structural and catalytic properties (Soetan *et al*, 2010). It also functions in assisting in the incorporation of Fe in haemoglobin, absorption of Fe from the gastrointestinal tract (GIT) and transfer of Fe from tissue to plasma. Copper is also required for growth and formation of bone and myelin sheath in the nervous system.Zinc is a catalytic component of over 300 enzymes playing roles in structural integrity of proteins and membranes, in the union of hormones to its receptors, and in gene expression (Hambidge, 2000). It is required for growth, normal development, DNA synthesis, immunity and sensory functions. Manganese plays an important role in bone development and is also involved in the metabolism of amino acids, lipids and carbohydrates. It also serves as a cofactor responsible for activating various enzymes including mitochondrial Mn superoxide dismutase, glutamine synthetase and arginase (Soetan *et al*, 2010).

The concentrations of the various elements measured in the plantain samples were, in order to determine their significance, compared with the Recommended Dietary Allowance (RDA) or Adequate Intake (AI) values for the various nutrient elements. The RDA's or AI's (presented in table 2b above), determine how much of the nutrient elements must be present in food consumed in a day to meet the requirement for normal growth and development of the body (WHO/FAO/IAEA, 1996). If food consumed in a day does not meet the Recommended Dietary Allowance (RDA) or Adequate Intake (AI) value, deficiency diseases may result. In much the same way, Upper Limit (UL) values have been set for some of these elements such that if the amount consumed in food exceeds this value, toxic effects may be experienced (NRC, 1989; IOM, 2002).

The concentrations of the elements and their respective RDA's or AI's however, are not directly comparable since these values have different units (g/day for RDA's and AI's whilst the concentrations are in units of mg/kg). If the average amount of plantain consumed in a day by Ghanaians was know, it would be possible to determine whether consuming that amount of the plantain samples studied in this work would be below, equal to or above the RDA's or AI's based on the assumption that only plantain was consumed throughout the day. However, owing to the lack of this data (on the amount of plantain consumed in a day by Ghanaians on the average), we could only deduce from our results how much plantain one must consume to meet the RDA and AI values of the various elements, and probably, the amount beyond which toxic effects might begin to manifest.

For the major nutrients indicated in parenthesis, the range of masses (dry mass obtained after freeze drying) of the various plantain samples, 686 – 2626 g (Ca), 762 – 2138 g (Cl), 276 – 2611g (K), 269 – 381 g (Mg) for females, 307 – 433 g (Mg) for males and 18029 – 35427 g (Na) would have to be consumed to meet the RDA/AI. The range of dry masses of the plantain samples 345 – 349 g (Cu), 93 – 216 g for females, 128 - 297 g for males (Mn) and 132 – 1091 g for females, 162 – 1333 g for males (Zn) must be consumed in a day to meet the RDA/AI for the micro nutrients in parenthesis. These values are based on the assumption that plantain alone is consumed; barring inputs from all possible sources of nutrient elements such as, soup, gravy, stew, sauce, condiments and other accompaniments.

The results imply that consumption of more than 216 g in females and 297 g in males of dry plantain would lead to intake of Mn above the AI value. Also, when a female consumes dry plantain above 381 g or a male consumes plantain above 433 g, the supply of Mg to their bodies would be above the RDA value for Mg. Likewise, 349 g is the maximum amount of dry plantain one must consume to meet the RDA for Cu. On the contrary, a minimum amount of 18,029 g of dry plantain consumption is required to meet the RDA of Sodium. For Ca, Cl and K, a maximum of up to 2626 g, 2138 g and 2611 g respectively of dry plantain could be consumed without exceeding their respective AI values.

These results revealed that although K recorded the highest concentration in the plantain samples followed by Cl, with regard to the RDA/AI values plantain is relatively richer in Mn, Cu and Mg than K. The results also spelt out the reason why one must not eat only one type of food at a meal but rather different types of food to make a nutritionally balanced meal. This is because in this case, whilst one may try to eat enough plantain to meet the RDA of Na, as an example, all the other elements would be way above their UL values and could therefore result in toxic effects. On the other hand, if one ate just enough plantain to meet the RDA for say Mn; deficiency diseases due inadequate intake of the other elements would be the consequence. However, since plantain is normally served with soup, stew, gravy, palava sauce, avocado pear, meat or fish, and also since other foods may be served along with plantain at a meal, it is likely the other foods and accompaniments would provide enough nutrients to supplement those in the plantain.

The results obtained in this work compared favourably with those obtained by Danso *et al* (2006) in a similar study carried out in a non mining area. The results obtained by Danso *et al* (2006) were: Cl (1529 – 2054) mg/kg, Cu (3.0 – 20.5) mg/kg, Mg (0.023 – 0.235) mg/kg, Mn (49.54 – 126.23) mg/kg and Zn (1.32 – 3.62) mg/kg. This may suggest that the soils on which the plantains studied were cultivated at Bibiani have not been impacted negatively by the mining activities in terms of the fertility of the soil. On the contrary, application of household manure and other forms of fertilizers might have served to restore the fertility of the soil resulting in no indication of loss of soil fertility or any other factor that might be due to land degradation caused by mining activities.

The only significant difference however, observed in comparing our results with those of Danso et al (2006), was with the concentrations of Mg and Mn. Whilst in this study higher levels of Mg (946 – 1337) mg/kg and relatively lower levels of Mn (7.40 – 17.20) mg/kg were measured, the opposite being Mg (0.023 – 0.235) mg/kg and Mn (49.54 – 126) mg/kg was reported by Danso *et al* (2006). The results obtained in this work however, were consistent with the mineralogy of the Bibiani area which has Mg as a major element and Mn as associated trace element. The results obtained in this work for Mg and Mn were also consistent with the RDA of Mg and AI value of Mn.

Conclusion

The levels of the essential/nutrient elements Ca, Cl, Cu, K, Mg, Mn, Na and Zn in nine plantain samples from the Bibiani mining area and its environs have been determined. The concentrations of the major nutrients/minerals among them were in the ranges; 495 – 1895 mg/kg for Ca, 1076 – 3019 mg/kg for Cl, 1800 – 17000 mg/kg for K, 946 – 1337 mg/kg for Mg, and 42.34 – 83.20 mg/kg for Na. The concentration ranges of the micro/trace elements Cu, Mn and Zn were 2.55 – 25.44 mg/kg for Cu; 7.40 – 17.20 mg/kg for Mn and 8.25 – 67.96 mg/kg for Zn. The results support the claim that plantain contains high levels of K and low levels of Na.

However, with regard to the RDA/AI values of the various nutrient elements, it could be said that plantain is relatively richer in Mn, followed by Cu and Mg than K. This is due to the fact that relatively lower amount of plantain is required to meet the RDA/AI values of those elements than K. It could also be said that the levels of the nutrient elements measured in the plantain samples did not give any indication of impact of mining activities which could have resulted in loss of soil fertility since the results obtained in this work compared favourably with the results obtained in a similar study conducted by Danso *et al* (2006) in a non mining area. The only difference observed in the results obtained in this work from that of Danso et al (2006) was with the levels of Mg and Mn. The levels of Mg and Mn measured in this work were however, consistent with the geology of the area as well as their respective RDA/AI values. Also application of household waste which is a practice in most household gardens was suspected might account for the high levels of some elements like Cl and K measured in plantain samples from a household garden.

Acknowledgement

The authors wish to express their gratitude to the National Nuclear Research Institute of the Ghana Atomic Energy Commission for providing funds for this research work. We also wish to thank all individuals who have contributed in one way or another in this research work.

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