ECRONICON OPEN ACCESS

EC NUTRITION
Research Article

Selenium in Locally Produced Food Crops and Implications on Healthy Eating: A Case Study at the Talensi District of Ghana

Emmanuel Arhin* and Raymond Kazapoe

Faculty of Applied Sciences, Department of Earth and Environmental Sciences, University for Development Studies, Navrongo, Ghana

***Corresponding Author**: Emmanuel Arhin, Faculty of Applied Sciences, Department of Earth and Environmental Sciences, University for Development Studies, Navrongo, Ghana.

Received: March 29, 2017; **Published:** April 19, 2017

Abstract

Selenium deficiency in human and animal diets is a worldwide nutritional problem. Consumption of low-Se in diets will result in poor growth or even lead to death. Conversely, accumulating excessive Se in diets may show Se toxicity symptoms. This multifaceted characteristic of Se made it imperative to investigate the deficiency, adequacy, and toxicity of Se in the primary foodstuffs in Talensi District. 19 samples were analysed for Se of which 4 of the samples were field duplicates. The analysis of the duplicate samples for quality assurance of the analytical data was excellent as comparison of the original and duplicate sample results returned precise assays and plotted within the 95th percentile zone. The investigation recognized the same food crops to have variable Se concentrations and these were attributed to variations in underlying geology and the local environmental activities. There were even instances where some crop's Se measurements were below detection limit. However, the average concentrations of Se in the two food groups; cereals and legumes found Se enrichments to be in this proportions in sorghum (28%), millet (24%), groundnut (23%), rice and soybean (9%), guinea corn (5%) and maize (2%). Yet there were some food crops that measured below detection in some communities. Examples were millet at Shega, maize at Vunania, groundnut at Tonzug and guinea corn at Tongo and Bundunia. On the basis of the available data the authors conclude the consumption of sorghum, millet and groundnut to mitigate Se-related diseases and recommend the application of Se-based fertilizers in maize, guinea corn and rice farming as they form major foods for the majority of the population in Ghana.

Keywords: *Deficiency; Adequacy; Toxicity; Geographic Space; Concentrations; Food Crops*

Introduction

There are many trace elements in soils that are modified and transformed through soil-plant root interactions and are transported to other organs of the plants and later consumed by humans as food. Nutritionists and dietitians refer to these as essential nutrients useful for the development of human body. Common essential nutrients are nitrogen (N), calcium (Ca), phosphorus (P), potassium (K), magnesium (Mg), zinc (Zn), iron (Fe), nickel (Ni) etc. Research has shown that 99% of the human body is made up oxygen, carbon, hydrogen, nitrogen, calcium and phosphorous. Only about 0.855 is made up of potassium, sulphur, sodium, chlorine and magnesium. However, there are other trace elements that have specific biochemical functions in the human body and these are iron, cobalt, copper, zinc, manganese, molybdenum, iodine and selenium. Although these elements are required in small quantities they are vital for maintaining human health. For instance, anaemic disease is attributed to lack of iron and recommendation for bone building is calcium-supplemented drug. At the mention of goitre, iodine deficiency will be the suspect. All these led to the testimony that the trace elements are part of enzymes, hormones and cells in the body. It thus suggests that the human body needs an optimum amount of them to function well and hence any insufficient intake of the trace minerals can cause symptoms of nutritional deficiency. However, to a nutritionist your needs for these trace elements can be met by eating a variety of foods from the different food groups. This assertion was very true before the advent of climate change resulting in rapid evolutions of regolith and landforms and critically influencing the concentrations and distributions of all metal ions including the trace elements. This is the source of motivation of the authors to investigate the trace element contents of selenium in food crops in the Talensi area, to evaluate their geographical variations in relationship to their concentrations, to guide in providing correct advice and to counsel people who visit our facilities. Selenium is chosen for this investigation because it is least talked about among the essential nutrients. However, it works as an antioxidant that prevents damage to cells and some cancers and is essential for normal functioning of the thyroid gland. There are reports that areas with enriched Se have low prevalent HIV/AIDS in some countries in Africa [1]. There are currently some reported cases of cancerous and HIV/AIDS cases in Ghana so this makes Se investigation in food very logical as most trace elements uptake to human body is via the food groups. In the context that Se can prevent many health issues and are obtainable through the local diet, this paper therefore, examines the contained Se in selected staple foods; cereals and legumes cultivated and consumed by the people of Talensi District with the objective of establishing the relationship between the concentration variabilities of this essential trace element in most of the staple food in the area. Food crops with deficient and excess concentrations based on the geographical locations will be highlighted to attract Public Health attention in order to address any nutritional shortfall in Se in diets to avoid related health consequences from its deficiencies.

Location, geology, physiographical setting

Location and Geology

Talensi District is one of the newest districts carved out from Talensi-Nabdam District of the Upper East Region of Ghana. It is situated about 45 km southeast of Bolgatanga the regional capital, and located 850 km from Accra, the national capital. Access to the district by road from Accra is via a northerly first class road through Kumasi, the second largest city in Ghana.

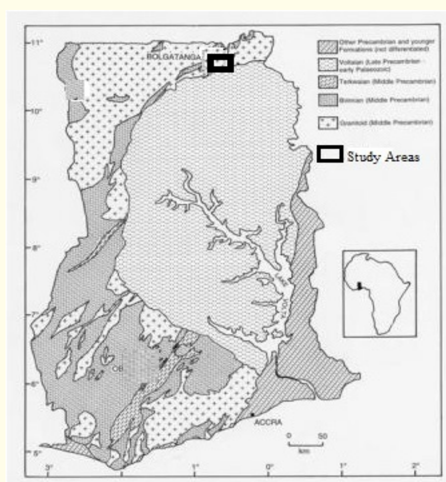

Figure 1: *Location and Regional Geology of Ghana (Ghana Geological Survey Map, 2004).*

The rocks of the area comprise Volcanic and Sedimentary lithologies ([2]; Figure 1) with varying degrees of metamorphism. Characterizing the transition between the Birimian Volcanic Belt and the Sedimentary Basin is the Volcano-sedimentary suite of rocks. The Volcanic units consist of basalt, andesite, dacite etc. and these rocks constitute the Volcanic Greenstone Belts of the Birimian of Ghana. The Volcano-sedimentary rocks are made up of amphibole schist, biotite-hornblende schist, sericite schist, tuff and some pyroclastic rocks ([3]; Figure1).

Physiography

The climate is savannah with single rainy season. The rainfall starts sluggishly from March and peaks generally in August or September after which there is a sharp decrease after October [4]. The annual rainfall is about 600 - 1200 mm [5] with mean monthly rainfall of about 986 mm. Drops in rainfall occur either in August or September. Temperatures are frequently high with monthly means at 28.6°C which drop to a minimum of 26.4°C during the rainy seasons. Lowest temperatures of ≤ 22°C occur between November and January due to the harmattan. However, maximum temperatures rising above 40°C often in the months of March and April have been recorded in the past [6].

Methodology

Food samples considered staple in the diets of the people of Talensi District were collected for the analysis of Se contents. These food crops were categorized into two food-groups; cereals and legumes and comprise millet, rice, maize, soybean, sorghum and Guinea corn. Nineteen food samples were randomly collected from different geographic areas in Talensi District during the main harvest season. Out of the nineteen samples; 5 samples were collected from millet, 3 from sorghum, 3 from groundnut and 2 each from maize, rice and soybean respectively. In order to keep the samples in powder form, all the 19 samples were oven dry at a temperature of 80°C after which they were pounded separately using porcelain mortar and pestle into powder keeping sampling preparation protocols to avoid sample contaminations. In this study 30 g weight sub-samples were collected from each powdered sample, kept in a labelled Kraft paper for trace elements chemical analysis using flame Atomic Absorption Spectrophotometer. The elemental concentrations of Se in the principal food crops were analyzed and interpreted relative to their deficiencies and enrichments.

Laboratory sample preparation and analysis

The flame Atomic Absorption Spectrophotometer analysis was performed on 0.5 g sub-samples weighed from the powdered food samples at the laboratory. In this analysis, 2 ml hydrogen peroxide and 20 ml of nitric acid were added to the different 0.5 g sub-sampled portions of powdered food samples. The mixture i.e. the sub-samples, hydrogen peroxide and the nitric acid were placed in a beaker. They were covered and later placed on a hotplate. The content of the beaker was heated for 3 hours to digest the mixture until a transparent solution was obtained. The digested material was allowed to cool at room temperature. Thereafter, 30 ml of deionized water was added and the mixture filtered using 45 mm pore space filter paper. Se contents in the food crops were measured from the resultant digested samples.

Results

The results of Se in the two food crops returned variable concentration values sometimes even among the same food type. Table 1 is the results of Se in the seven listed food crops collected from different geographical location. Samples that assayed below the detection limit (DL) of the analytical technique were assigned a value of 0.0005 mg/kg. This value was used only for data appraisal convenience and is not the certified detection limit for flame atomic absorption spectrometer. In this investigation, global permissible limits of 0.005 mg/kg for both cereals and legumes were used [7]. This permissible limit was used as the threshold value below and above which a deficiency and enrichment occurs. This boundary value helped in computing the enrichment factors (EF) of Se in the food crops from the various geographic locations. The percent enrichment or deficiency was obtained as:

$$\%\ Se\ Enrichment = \frac{Concentration\ in\ Sample\ X - Permissible\ Value}{Concentration\ in\ Sample\ X} \times 100\%$$

Community	Crops	Se (mg/l)	EF (Se)	EF (Se)%
Balungu	Millet	0.12	0.115	95.8
Balungu	Millet	0.24	0.235	97.9
Kaari	Millet	0.24	0.235	97.9
Sheaga	Millet	0.0005	0.0045	
Pusunamago	Millet	0.18	0.175	97.2
Pusunamago	Sorghum	0.12	0.115	95.8
Sii	Sorghum	0.12	0.115	95.8
Sii	Sorghum	0.3	0.295	98.3
Tongo	Guinea corn	0.0005	0.0045	
Bundunia	Guinea corn	0.0005	0.0045	
Kaari	Guinea corn	0.12	0.115	95.8
Tonzug	Groundnuts	0.3	0.295	98.3
Tonzug	Groundnuts	0.0005	0.0045	
Vunania	Maize	0.0005	0.0045	
Vunania	Maize	0.0005	0.0045	
Gognia	Rice	0.12	0.115	95.8
Navrongo	Rice	0.0005	0.0045	
Datoko	Soybean	0.12	0.115	95.8
Yameriga	Soybean	0.0005	0.0045	

Table 1: *Concentrations and enrichments of Se in some staple food crops at Talensi District.*

In Table 1 where the measured concentrations of Se were below detection limit, the columns were left blank in the per cent enrichment [EF (Se) %] column. The summary statistics of Se in food crops normalized with respect to global Se permissible limits in food [7], permissible limit of Se in food in Mayland [7] and Yang., *et al*. [8] permissible limits of Se also in food crops are presented in Table 2. Pie chart showing the percent enrichments of the sampled food crops is shown in Figure 2. It also demonstrates the Se enrichments of the two food-groups i.e. cereals and legumes (Figure 2) in the district.

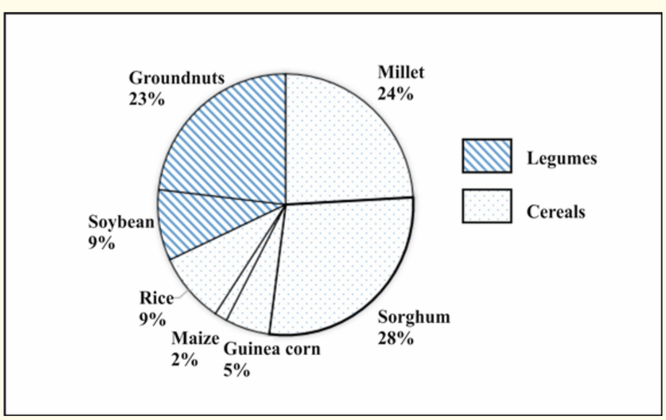

Figure 2: *Proportional enrichment (%) of Se in staple food crops at Talensi District.*

Se in crops	Permissible Limits	Max	Min	Median	Mean	SD	EF
Millet	0.005	0.24	DL	0.18	0.156	0.1004	0.151
Sorghum	0.005	0.3	0.12	0.12	0.18	0.10392	0.175
Guinea corn	0.005	0.12	DL	0	0.04	0.06928	0.035
Maize	0.005	DL	DL	0	0	0	0.01
Rice	0.005	0.12	DL	0.06	0.06	0.08485	0.055
Soybean	0.005	0.12	DL	0.06	0.06	0.08485	0.055
Groundnuts	0.005	0.3	DL	0.15	0.15	0.21213	0.145

Table 2: *Summary statistics of Se in some staple food crops at Talensi District.*

The analytical quality of the data from the laboratory was also monitored using field duplicate samples inserted into the batch of samples to the laboratory and the plot of the results is presented in Figure 3.

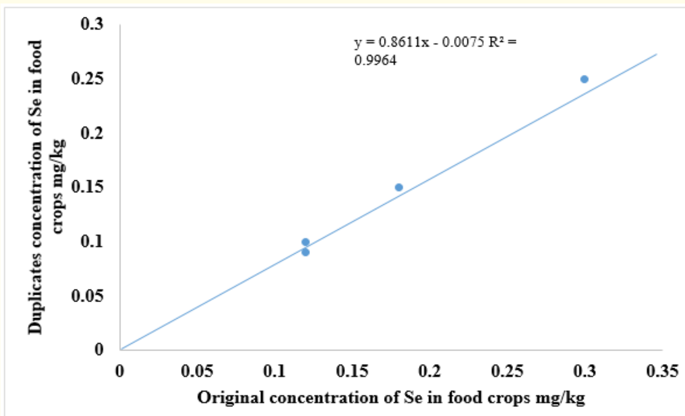

Figure 3: *Plot of field duplicates and original samples in the assessments of the quality of the analytical data.*

Discussions

Selenium does a lot of work in humans to make us healthy. Its presence in our bodies is for wellbeing purposes. Deficiency of it may create many health problems. Paramount among its contributions to human's general wellbeing is Se works as an antioxidant to prevent cells damage along with vitamin E and has been reported to prevent some cancers, HIV/AIDS and is essential for normal functioning of the thyroid glands. Knowledge of the right amount of Se in the diet digested by humans does not only emanate from the food group but the environment of cultivation. This is very important because each geographical location is underlain by different set of geological materials, which weathers or decomposes into soils where the food crops are cultivated. Often it is said that contaminated lands are able to mobilise and transport the contaminants in the localised environments. Roots of the cultivated food crops take up the micronutrients from the soils to different organs of the plant. Therefore, the notion that rock is an aggregate of minerals [10] and is transformed into soils via weathering processes, can results in different elements or micronutrients occupying different geographical areas in the District. It may not be correct to assume same concentrations and distributions of essential micronutrients in the same food groups. It is apparent that local environmental activities can influence the concentrations and distributions of the micronutrients or trace elements. Therefore, as advocates on matters of food and nutrition impacts on health, caution needs to be taken when making blanket pronouncements for types of food crops enriched in particular essential trace elements.

Deficient concentrations of many trace elements have resulted in several health problems but as indicated by Arhin and Zango [10] trace elements-related diseases require more than drug prescriptions by medical doctors. Besides there are many affected people that are financially cash trap and cannot afford the prescribed drugs. These groups of people will want to depend on food crops enriched in the respective essential micronutrients to maintain the appropriate levels of essential trace elements to keep healthy. Research works by Arhin and Zango [10], Centeno., *et al*. [11] and Kubota and Alloway [12] give testimony of the impact of natural environment from trace elements on public health. As seen in Table 1, the measured concentrations of Se in the food crops were different. The two samples collected from millet from Balungu; two samples from Sorghum at Sii and two samples of groundnut from Tonzug all had different measured Se concentrations. In this investigation to assess the enrichments of Se in the food crops no certified reference materials were inserted in the batch of samples sent to the laboratory for analysis but field duplicates were included to check the quality of the analytical data. As seen in Figure 3 the analytical quality of the analysis was within acceptable interval as the duplicate sample results were not very different from the original food sample results. This makes the underlying geology and the local environmental activities chief causes on the Se concentrations in the same food crops example millet from different geographical or landscape locations. Most people in this district are farmers but it is unclear whether Se-based fertilizers are used in farming by all or there are some who fail to apply fertilizers in farming. This investigation is unable to respond to that question and will be looked at in the next study. However, it is clear that lithologies and soil forming processes in the district vary. On this basis, one can anticipate Se-rich soils to have food crops grown in them to be rich in Se and the vice versa. This confirms the different concentrations of Se in food crops reported by Fordyce [13]. Also, different concentration limits (Table 2) defined by WHO [9], Mayland [7] and Yang., *et al.* [8] may be an attribute of the underlying geology producing the soils in the cultivated areas as well as the local environmental activities.

The changing climate has implications on health [14] as it impacts on trace element concentrations and distributions in food crops. Nutritionist provides nutritional programs based on the health needs of patients or residents and counsel patients on how to lead a heathier lifestyle. Administering this program is practicable in the developed nations, as many people know their health status. Same cannot be said about the developing countries, example the study area. Clinical test to evaluate health status generally seem nonexistence but the local people believe in consuming certain food crops to make up of certain essential micronutrient lost. This notion just was true before the advent of climate change. However, with changes in climate the critical zone of the earth is evolving rapidly and therefore affecting trace elements in the environment [10] and impacts on public health [15] and consequently influence essential trace elements including Se in food crops. For instance, in Figure 2 sorghum and millet appear to be enriched in Se followed by groundnuts. The enhanced Se concentrations were 28%, 24% and 23% respectively for sorghum, millet and groundnut. On the other hand, rice, soybean, guinea corn and maize have low Se enrichments with maize registering the lowest. Rice and soybeans Se enrichment is 9%, Guinea corn is 5% and maize is 2%. However, from Wang., *et al.* [16] Se is known as an essential trace element for humans and animals. Its deficiency in food crops creates a worldwide nutritional problem whereas an adequate dietary intake of Se is necessary to keep humans, livestock and poultry healthy. The overall low enrichments of Se in maize (2%, Figure 2) and concentrations below detection at Vunania (Table 1) may result in a big nutritional health issue as maize is a primary fodder source of livestock and poultry and one of the main food sources for humans in Ghana. Additionally, the publication on investment opportunity in Ghana by Millennium Development Authority place maize as the largest staple crop in Ghana and contributes significantly to consumer diets. From Figure 2 all the three food crops contain Se in deficient amounts and therefore buttress the point that dieticians or nutritionist in advising people on healthy eating should factor in some local content data. For instance, as seen in Table 2 soybean at Datoko is 95.8 % rich in Se whereas soybeans at Yameriga the nearby community in the same district show Se deficiency. Similar scenario is seen in rice at Navrongo and Gognia. There is 95.8% Se enrichment in rice at Gognia with deficient enrichment of Se in Navrongo rice. The landscape positions of the rice farm at Gognia and Navrongo are not worlds apart but the soils in the two areas seem to have been developed from different lithologies. This could be part of the reasons for the differences in Se concentrations in same food crops.

Conclusions

From this investigation, it is evident that cereals are more enriched in Se than the legumes. However, it is not all the cultivated and consumed cereals in the district that are capable of preventing the Se-related diseases because of their degrees or differences in Se-enrichments. Though they are all bio-accessible and form the chief food crops in the district, millet show about 95.8% Se enrichment in some communities and an average of 28% in sorghum, 24% in millet and only 2% in maize. On the basis of these percentages (Figure 2) it is paramount on nutritionist to advice on the basis of the highest and lowest essential trace element in specific food crops rather than advising on the basis of general knowledge on food groups.

The revelation in this investigation is that the most consumed staple food maize is among the lowest Se-enriched crop in the District. Acknowledging the low concentrations of Se in maize and introducing Se-based fertilizers will contribute immensely in addressing the Se-related diseases that may emerge in future if not addressed. Wang., *et al*. [16] investigation reveals Se fertilizer strategy can effectively improve the Se content in edible crop parts and therefore application of such strategy in Talensi District can curtail the future outbreak of Se-related diseases. Alternatively balancing the food on the basis of the identified percentages in diets could be the way to go. Hence to get the nutritional advice properly to the population requires having a local database on the individual concentrations and enrichments of the essential or nutritional elements as the underlying geological settings varies with geographic space.

Acknowledgement

The authors are thanking the government of Ghana for supporting this research indirectly through a research allowance given to lecturers in Public Universities in Ghana. Though the amount was inadequate it was able to support the team during the fieldwork and sample preparation. We greatly appreciate this support from the government but will expect some increment to help unravel many of the issues that bothers on earth science, health and agriculture. We are also grateful to all who contributed in kind but their names are not mentioned here. Your contributions are greatly acknowledged. Finally, to our colleagues at the Department of Earth and Environmental Science, Navrongo campus and all members of Medical Geology Association, Ghana Chapter that had an opportunity to read and made suggestions to improve the quality of this work, we greatly appreciate your contributions.

Bibliography

1. Beck MA. "Selenium and host defence towards viruses". *Proceedings of the Nutrition Society* 58.3 (1999): 707-711.
2. Kesse G. "The Rock and Mineral Resources of Ghana". *A A Balkema, Rotterdam, Netherlands* (1985): 610.
3. Milési J P., *et al*. "West African gold deposits". Chronique de la recherché minière, BRGM Report No. 497 (1989): 3-98.
4. Webber P. "News from the village: agrarian change in Ghana". *Geography Review* 9.3 (1996): 25-30.
5. Dickson K B. "A historical geography of Ghana". *Journal of Asian and African Studies, Centre for Global Metallogeny* 7 (1972): 253-255.
6. Dickson K and Benneh G. "A New Geography of Ghana, metricated ed. Longman Group, London (1985): 451.
7. Mayland HF. "Selenium in plant and animal nutrition". Marcel Dekker, Inc., New York (1994).
8. Yang G., *et al*. "Endemic Selenium Intoxication of Humans in China". *American Journal of Clinical Nutrition* 37.5 (1983): 872-881.
9. World Health Organization. "Trace Elements in Human Nutrition and Health" (1996).
10. Arhin E and Zango MS. "Impact of Trace Element in the Natural Environment and Public Health: A Medical Geology Perspective". *Annals of Public Health and Research* 3.4 (2016): 1051.
11. Centeno JA., *et al*. "Medical Geology: Impacts of the natural environment on Public Health". *Geosciences* 6 (2016): 8.
12. Kubota J and Alloway WH. "Geographic distribution of trace element problems". In Mortvedt JJ, Giordano PM, Lindsay WL editors. Micronutrients in agriculture. Soil Science Society of America, Madison Winconsin USA (1972): 525-554.

13. Fordyce F. "Selenium deficiency and toxicity in the environment". In: Essentials of medical geology, impacts of the natural environment on Public health (2015): 373.

14. Arhin E., *et al*. "Trace elements distributions at Datoko-Shega artisanal mining site, northern Ghana". *Environmental Geochemistry and Health* 38.1 (2016): 203-218.

15. Emmanuel Arhin., *et al*. "The Hidden Dangers of Unknowingly Ingesting Harmful Trace Elements from Food Crops and their Health Implications: A Case Study at Talensi District in the Upper East Region, Ghana". *EC Nutrition* 7.1 (2017): 34-45.

16. Wang J., *et al*. "Increasing Se concentration in maize grain with soil- or foliar-applied selenite on the Loess Plateau in China". *Field Crops Research* 150 (2013): 83-90.

Volume 8 Issue 3 April 2017