



Selenium Contents of Common Cereal and Legume Staples in Central Nigeria

Saidu Zarmai¹, Ishaq S. Eneji^{1*} and Rufus Sha'Ato¹

¹Department of Chemistry, Federal University of Agriculture, P.M.B. 2373, Makurdi, Benue State, Nigeria.

Authors' contributions

This work was carried out in collaboration among all authors. Author SZ performed the sampling and the analysis. Author ISE co-supervised the research and wrote the draft of the manuscript. Author RSA designed the study and vetted the manuscript as major supervisor of the research. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/CJAST/2019/v36i430241

Editor(s):

(1) Dr. Ahmed Fawzy Yousef, Associate Professor, Department of Geology, Desert Research Center, Egypt.

Reviewers:

(1) Aba-Toumnou Lucie, University of Bangui, Central African Republic.

(2) Ramazan Dogan, Türkiye.

Complete Peer review History: <http://www.sdiarticle3.com/review-history/36506>

Original Research Article

Received 10 September 2017

Accepted 17 November 2017

Published 17 July 2019

ABSTRACT

The selenium contents of three selected cereals (maize, millet and sorghum) and four selected legumes (soybeans, groundnuts, white and brown beans) grown and consumed in Central Nigeria was determined using hydride generation–atomic absorption spectrophotometry (HG–AAS). Results of the analysis showed that mean concentrations ($\mu\text{g}/\text{kg}$) of selenium in the cereals were 82.2 ± 27.7 ; 57.8 ± 12.2 and 38.6 ± 7.9 for maize, millet and sorghum, respectively. Similarly, analytical results showed that among the legumes, brown beans contained the highest mean selenium contents ($82.5 \pm 18.9 \mu\text{g}/\text{kg}$), followed by ground nuts ($66.5 \pm 15.4 \mu\text{g}/\text{kg}$); the contents in soybeans ($35.7 \pm 9.3 \mu\text{g}/\text{kg}$) and white beans ($34.7 \pm 7.2 \mu\text{g}/\text{kg}$) were comparable. The mean values for selenium contents obtained in this work are generally higher than literature values for similar foodstuff, most of the values lie within the limit referred to as lower and safe upper reference nutrient intake. The differences could be determined due to the total selenium concentration and its bioavailability in the soils on which these crops are grown. The trend of selenium contents in the cereal and legume staples was as follows: maize > brown beans > groundnuts > millet > sorghum > soybeans > white beans.

*Corresponding author: E-mail: ishaqeneji@gmail.com;

Keywords: Selenium; accumulator; staple foods; Central Nigeria; HG-AAS.

1. INTRODUCTION

Plants and animals assimilate selenium (Se) to varying degrees. Evidence for whether Se is essential for plant and crop health is equivocal, but plants can be divided into three groups: Se – accumulators, Se – indicators (or secondary Se – accumulators) and non-accumulators. Non – accumulators rarely assimilate more than 100 mgkg⁻¹ Se (dry weight), where as Se accumulators can contain up to 40,000 mgkg⁻¹ Se (dry weight) when grown in seleniferous environment [1]. In non-accumulator cereal crops (such as wheat, oats, rye and barley are non-accumulators) the grain and roots often contain similar amounts of the element whereas concentration in the stems and leaves are lower [2,3]. The only Se accumulator plant regularly used as a food source is the tree *Bertholletia excelsa*, which produces Brazil nut, which are known to be richest source of dietary Se. However, some common crop species, for example *Brassica* species (rape seed, calabrese broccoli, cabbage) and *Allium* species (garlic, onions, leeks and wild leeks), are secondary Se-accumulators.

Selenium is an essential trace mineral and powerful antioxidant. In biological systems the element is a constituent of some amino-acids [4]. While essential to humans and animals in trace amounts, it can be harmful in excess. It has a very narrow range between dietary deficiency and excess; the lower reference nutrient intake (LRNI) is set at 40 µg per day and a safe upper level of intake set at 450 µg per day [5]. In animals and humans, this element forms a vital constituent of biologically important enzyme glutathione peroxidase [6]. Selenium deficiency has been linked to decreased appetite, growth and reproductive fertility, as well as muscle weakness [7]. Deficiency of the element has also been linked to other reproductive disorders, impaired immune system function, Keshan Disease (Cardiomyopathy) and Kashin-Beck Disease (Osteoarthritic disorders), diabetes, muscular sclerosis, muscular dystrophy and cancer [6]. Currently, there is growing interest in the role of selenium deficiency in emerging viral diseases such as avian flu and HIV/AIDS. Viral mutagenicity has been proven to occur in selenium deficient conditions and many of these emerging diseases come from selenium-deficient parts of the world [8].

In most cases, food forms the major source of selenium for humans as its concentration in water and air are extremely low [9]. The concentration of selenium in food stuffs depends upon the selenium concentration of the soil on which the food was grown [10]. Brazil nuts which contains 554 µg/kg selenium is the richest staple food in the world and forage crops containing less than 40µg/kg selenium are generally associated with deficiency in grazing animals [11]. Selenium concentration of most soils is very low ranging from 0.01 to 2 mg/kg but high concentration of up to 1200 mg/kg have also been reported in some seleniferous areas [12]. The estimated lower and safe upper reference nutrient intake values have been documented [11].

Cereals and legumes based products are the most important source of food and provide the major source of energy and protein for a majority of people in developing countries, including Nigeria [13]. Considering the health implications of a selenium-deficient diet in a population, we decided to investigate the selenium contents of some of the common selected cereals and legumes grown/consumed in Central Nigeria, since there is little or no information available on their selenium contents. This research is significant in that, it will shade light on which of the staples contain higher contents of selenium.

2. MATERIALS AND METHODS

Sample of cereals (maize, millet and sorghum) and legumes (soybeans, groundnuts, white and brown beans) were collected in central markets of Minna, Bida, Abuja, Keffi, Lafia, Makurdi, Gboko, Otukpo, Lokoja, Idah, Ilorin, Lafiagi and Jos in Central Nigeria (see Fig. 1.) in January, 2012. Central Nigeria is an agricultural zone that produces more of these cereals and legumes in Nigeria. The samples were packed in well labeled polyethylene bags noting the food types and area of collection. Samples were transported to laboratory and cleaned to remove empty, diseased seeds and debris [14].

Samples were washed with distilled water and allowed to dry. Each sample was oven dried at 105°C to constant weight for about 2 – 3 hours. The oven dried samples were crushed in a ceramic mortar and pestle, sieved with the mesh of aperture 2 mm and stored in moisture resistance plastic bottles [15]. One gram of each crushed samples was weighed into a 30 mL

crucible with lid. Exactly 10 mL of Concentrated HNO_3 (70.5 – 96 % AR) was then added and the mixture placed on hot plate maintained at 60°C for 30 minutes, after which it was brought down and allowed to cool. Subsequently, 30mL of H_2O_2 (30 %) was added and the digestion was continued at 120°C for an hour [12]. After cooling the sample, it was diluted with de-ionized water and finally filtered. The filtrate was diluted to a total volume of 100 mL volumetric flask. The filtrates were stored in plastic sample bottles in fridge prior to analysis. A reagent blank sample was prepared similarly to account for possible contamination. Selenium contents in the digest was determined using hydride generator (GBC – HG – 3000) – atomic absorption spectrophotometer (GBC – Avanta) at Fugro Nigeria limited, Port-Harcourt. Determinations were in duplicate. Statistical analysis was

performed using SYSTAT version 16.0 (SPSS, USA).

3. RESULTS AND DISCUSSION

A total of thirty nine (39) samples of cereals and fifty two (52) samples of legume staples were analyzed from thirteen (13) sampling stations in Central Nigeria. The summary statistics of mean selenium contents in cereal and legume staple crops were presented in Table 1 with their standard deviations, minimum and maximum values. The pattern of mean selenium contents in the cereals was observed to be: maize > millet > sorghum while the legume was brown beans > ground nuts > soybeans > white beans. Figs. 2 and 3 show the selenium contents in the selected cereal and legume staple crops respectively, along the sampling areas in the Central Nigeria.

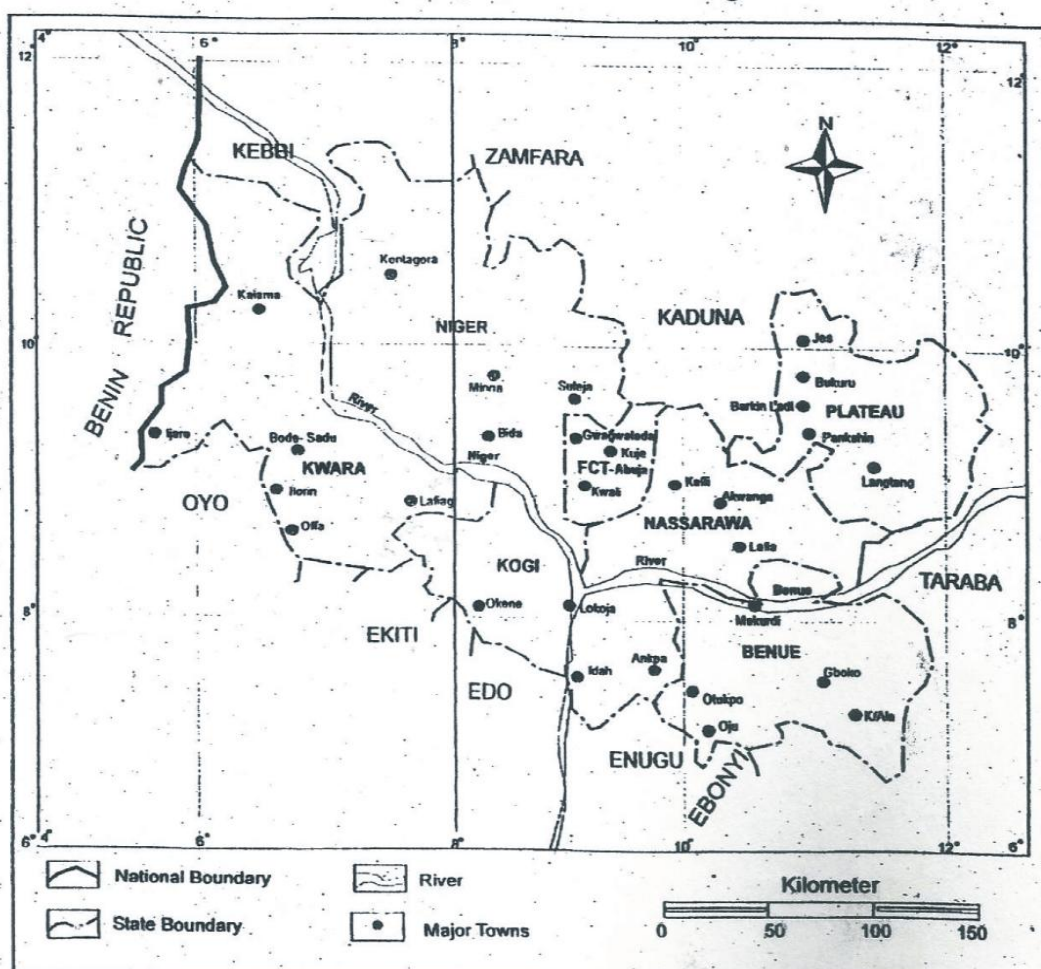


Fig. 1. Map of central Nigeria showing major towns

Source: Logman school Atlas, 2003 [14]

Table 1. Mean selenium contents ($\mu\text{g}/\text{kg}$) of some common cereals and legumes samples

Types	Species	Number of samples	Mean and standard deviation	Minimum	Maximum
Cereals	Maize (<i>Zea mays</i>)	13	82.2 \pm 27.7	0.01	392
	Millet (<i>Bajra pennisetum americanum</i>)	13	57.8 \pm 12.2	0.01	172
	Sorghum (<i>sorghum bicolor</i>)	13	38.6 \pm 7.9	0.01	101
Legumes	Soybeans (<i>Glycine max</i>)	13	35.7 \pm 9.3	0.01	92.6
	Groundnuts (<i>Arachis hypogeal</i>)	13	66.5 \pm 15.4	0.01	211
	White beans (<i>Vigna unguiculata</i>)	13	34.7 \pm 7.2	0.01	68.2
	Brown beans (<i>Vigna unguiculata</i>)	13	82.5 \pm 18.9	0.01	226

Selenium contents of maize samples ranged from 0.01-392 $\mu\text{g}/\text{kg}$ with Bida sample having the highest (392 $\mu\text{g}/\text{kg}$) while Otukpo, Idah and Jos samples having below detection limit ($< 1.00 \mu\text{g}/\text{kg}$) with the mean of 82.2 \pm 27.7 $\mu\text{g}/\text{kg}$. In millet samples this varied between 0.01 – 172 $\mu\text{g}/\text{kg}$ with Lafia sample containing the highest (172 $\mu\text{g}/\text{kg}$) while Bida sample having below detection limit ($< 1.00 \mu\text{g}/\text{kg}$) with the mean of 57.8 \pm 12.2 $\mu\text{g}/\text{kg}$. Selenium contents of sorghum ranged from 0.01 – 101 $\mu\text{g}/\text{kg}$ with Lokoja sample having the highest (101 $\mu\text{g}/\text{kg}$) while Keffi and Idah samples containing below detection limit ($< 1.00 \mu\text{g}/\text{kg}$) with the mean of 38.6 \pm 7.9 $\mu\text{g}/\text{kg}$.

Statistical analysis of variance between and within the data of cereal crops (maize, millet and sorghum) revealed that there was no significant difference ($P > 0.05$) in selenium contents ($\mu\text{g}/\text{kg}$) determined from maize, millet and sorghum in Central Nigeria. Multiple mean comparisons using Tukey Honest Significant Difference (HSD) test showed that there was no significant difference ($P > 0.05$) in selenium contents ($\mu\text{g}/\text{kg}$) in cereals determined. Homogeneous subset test revealed that there was correlation ($\alpha = 0.05$) between maize, millet and sorghum. The result of this analysis is further confirmation that cereal staples are non-selenium accumulators [5].

As presented in Fig. 3, the Se contents of soybeans samples in Central Nigeria ranged from 0.01 - 92.6 $\mu\text{g}/\text{kg}$ with Lafia sample containing the highest (92.6 $\mu\text{g}/\text{kg}$) while Abuja, Idah and Lafiagi samples containing below the detection limit ($< 1.00 \mu\text{g}/\text{kg}$) of the instrument with the mean of 35.7 \pm 9.3 $\mu\text{g}/\text{kg}$. Selenium contents obtained from ground nuts samples varied from 0.01 - 211 $\mu\text{g}/\text{kg}$ with Bida sample having the highest (211 $\mu\text{g}/\text{kg}$) while Minna and

Jos samples having below detection limit ($< 1.00 \mu\text{g}/\text{kg}$) with the mean of 66.5 \pm 15.4 $\mu\text{g}/\text{kg}$. Selenium contents of white beans ranged between 0.01- 68.2 $\mu\text{g}/\text{kg}$ with Ilorin sample containing the highest (68.2 $\mu\text{g}/\text{kg}$) while Keffi, Otukpo and Idah samples having below detection limit ($< 1.00 \mu\text{g}/\text{kg}$) with the mean of 34.7 \pm 7.2 $\mu\text{g}/\text{kg}$. Selenium contents obtained from brown beans varied from 0.01 – 226 $\mu\text{g}/\text{kg}$ with Lafia sample containing the highest (226 $\mu\text{g}/\text{kg}$) while Makurdi, Otukpo and Jos samples having below detection limit ($< 1.00 \mu\text{g}/\text{kg}$) with the mean of 82.5 \pm 18.9 $\mu\text{g}/\text{kg}$. The mean results of legume staples analyzed indicated that brown beans have the highest selenium contents (82.5 $\mu\text{g}/\text{kg}$), followed by ground nuts (66.5 $\mu\text{g}/\text{kg}$), then soybeans (35.7 $\mu\text{g}/\text{kg}$) and white beans the least (34.7 $\mu\text{g}/\text{kg}$).

Analysis of variance between and within the data of legumes (Soybeans, ground nuts, white beans and brown beans) showed that there was no significant difference ($P > 0.05$) in Selenium contents between brown beans, ground nuts, soybeans and white beans. Multiple comparisons using Tukey Honest Significant Difference (HSD) test revealed that there was no significant difference ($P > 0.05$) in selenium content in legumes determined. Homogeneous subset test showed that there was correlation between soybeans, ground nuts, white beans, and brown beans ($\alpha = 0.05$). The results of this analysis are clear confirmation that legume staples are also non-selenium accumulators [16].

Figs. 4 and 5 are bar charts of the mean Se contents of cereals and legume staples determined in this work. The values we obtained were within the range of literature values. Xue et al. [11] reported the following Se contents ($\mu\text{g}/\text{kg}$) for foods in the USA to be: canned tuna 63, cod 32, beef 35, brown rice 10, white rice 12 and chicken 20. IMFNB [5] reported the range of

staple foods between 40 – 450 µg/kg. Abulude et al. [17] reported also very high mean of selenium contents (millet 5 ± 3.4 mg/kg, rice 5 ± 2.5 mg/kg, white beans 10 ± 4.5 mg/kg, melon 5 ± 3.7 mg/kg, plantain less than 1 ± 8.4 mg/kg) in the Western part of Nigeria using AAS.

The differences in the selenium contents of the cereal and legume staples we selected and those in literature may basically be due to the total selenium concentration and its

bioavailability in the soil where these are grown [4,12,16]. Variations in the results of this analysis could also be attributed to the presence or absence of anthropogenic activities on the soils such as application of phosphate and sulphate fertilizers, pigments in glass and ceramic manufacture, antifungal agent in pharmaceuticals, fossil fuel combustion and light-sensitive photoconductor layer in photocopiers. In addition, as we eat a varied diet obtained from different geographical areas, it is unlikely that

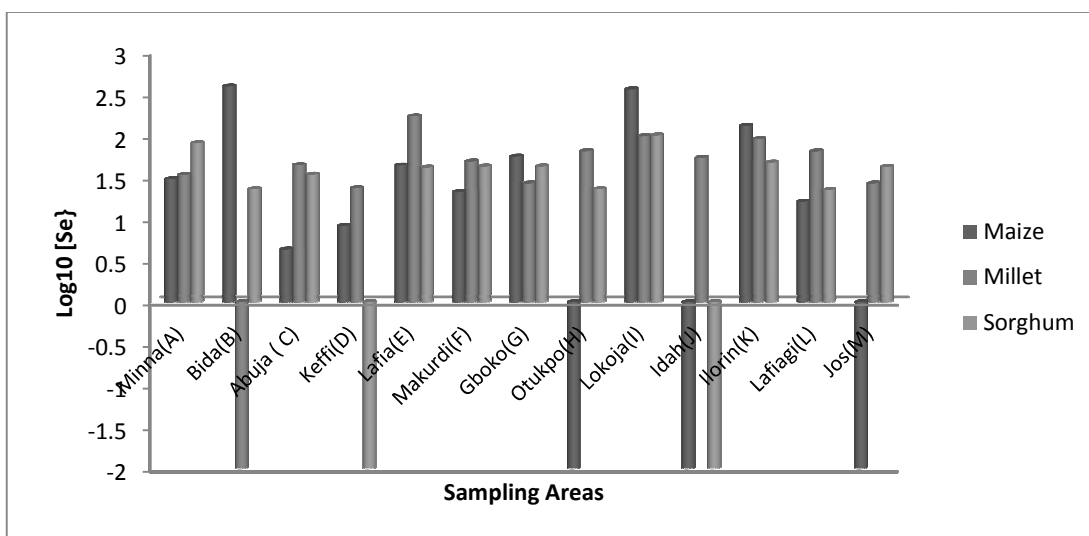


Fig. 2. Selenium contents (µg/kg; log values) of some common cereal staples

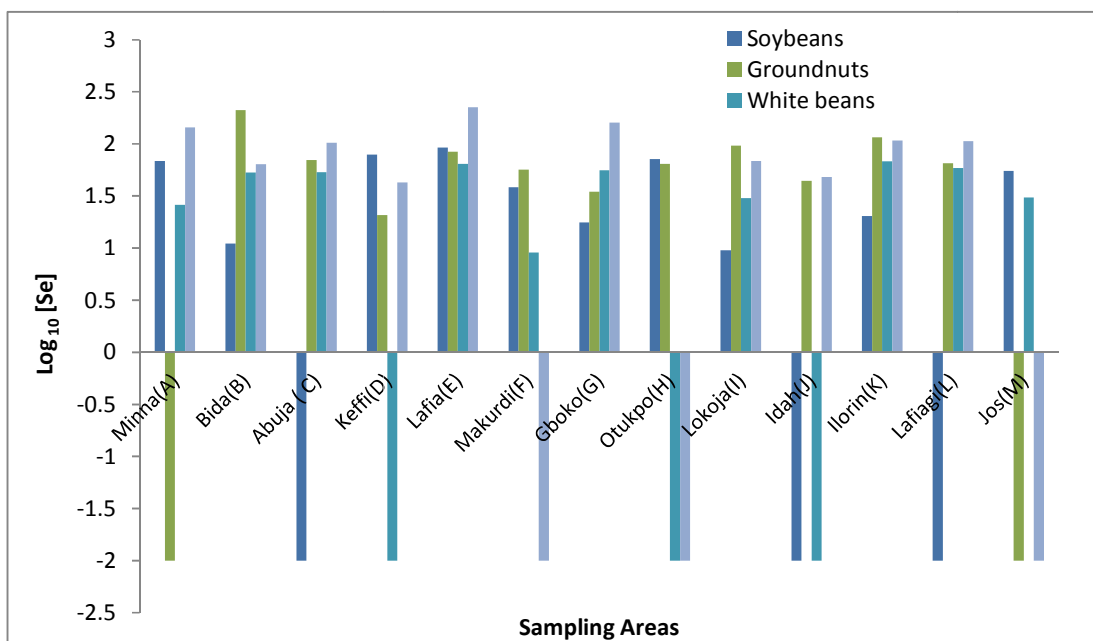


Fig. 3. Selenium contents (µg/kg; log values) of some common legume staples

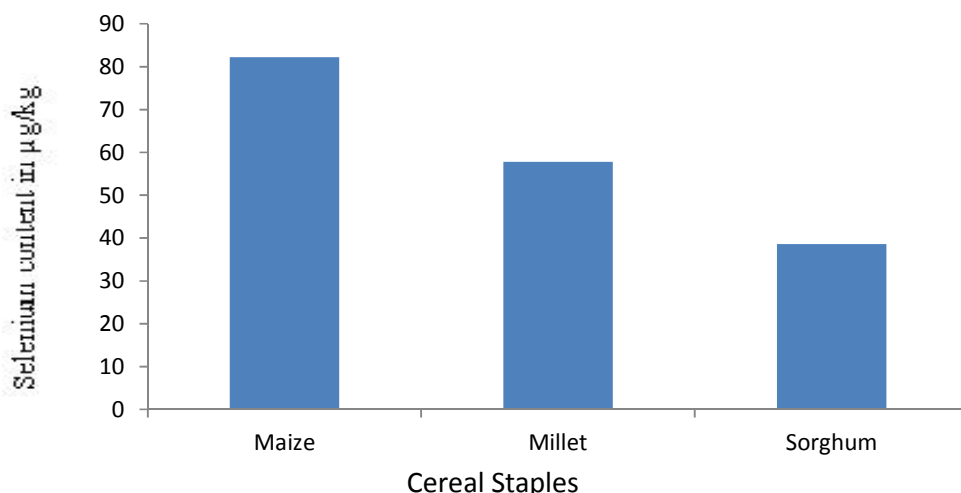


Fig. 4. Mean selenium contents (µg/kg) of cereal staples using HG - AAS

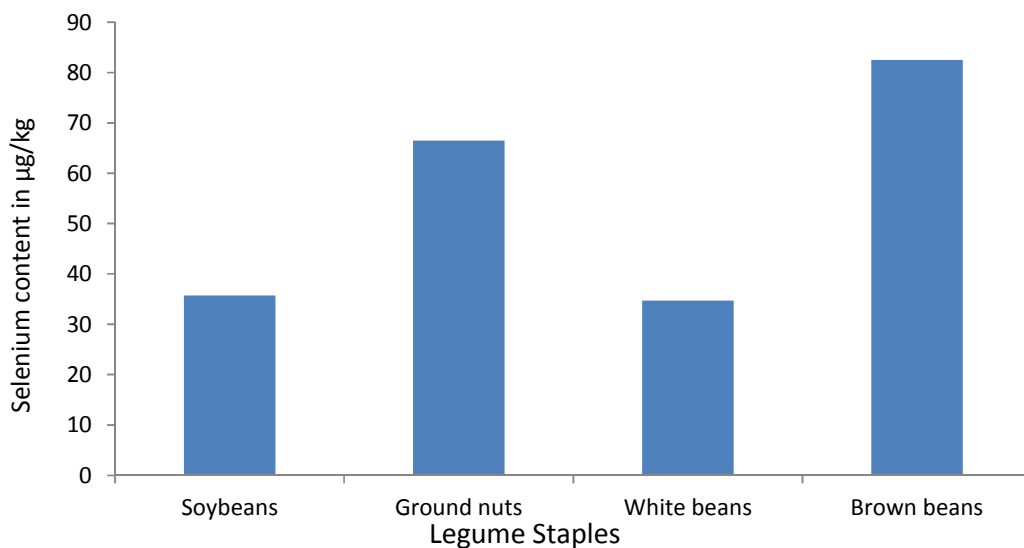


Fig. 5. Mean selenium contents (µg/kg) in legume staples using HG-AAS

selenium deficiency in the soil in few locations will cause selenium deficient in Central Nigerians' diet. Everybody consumption will vary about the determined mean, depending on the amount of protein in the diet and particularly the amount of selenium rich foods which are eaten [8,18].

There have been several quoted maximum intakes of selenium: WHO/FAO/IAEA [19] quoted 400 µg Se/day, IMFNB [5] recommended 450 µg

Se/day, Nordic Group [20] considered an intake of 280 – 350 µg Se/day and Food Standard Australia New Zealand (FSANZ) [21] reported Australian RDI to be 85 µg Se/ day.

4. CONCLUSION

Analysis of Se contents shows one of the samples of cereals and legume staples indicates that most samples contained relatively large quantity of the element while few others had

below the detection limit. The level of Se contents in these cereals and legumes studied was a clear manifestation of geographical origin, bioavailability of the Se in the soil and anthropogenic activities. This work has shown that better food sources of selenium were maize, brown beans, groundnuts and millet. Sorghum, soybeans and white beans contained some reasonable contents of selenium and it is not likely that selenium deficiency occurs in Central Nigeria.

ACKNOWLEDGEMENT

Our appreciation goes to all the staff of Fugro Nig. Ltd. Port-Harcourt for given us opportunity to use their laboratory facilities to carry out this research.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

- Chen Y, Hall M, Graziano JH, Skvkvick V, Van Green A, Parvez F, Ahsan HA. A prospective study of blood selenium levels and the risk of arsenic related premalignant skin lesions. *Cancer Epidemiology Biomarkers and Prevention*. 2007;16:207–213.
- Los Alamos National Laboratory (LANL). *Handbook of Chemistry, CRC Handbook of Chemistry and Physics*, 18th Ed. 2001;21–24.
- Levander OA. The global selenium agenda. *Trace Elements in man and animals – 6. Proceedings of the 6th International Symposium on Trace Elements in man and animals*. Huley, L. S., Keen LS, Loonerdal CL, Rucker RB. Eds. New York Plenum Press Inc; 2005.
- Sunde RA. Selenium. In: Ross AC, Caballero B, Cousins RJ, Tucker KL, Ziegler TR, eds. *Modern Nutrition in Health and Disease*. 11th ed. Philadelphia, PA: Lippincott Williams & Wilkins. 2012;225–237.
- Institute of Medicine, Food and Nutrition Board (IMFNB). *Dietary Reference Intakes: Vitamin C, Vitamin E, Selenium, and Carotenoids*. National Academy Press, Washington, DC; 2000.
- Moroder L. Isoteric replacement of Sulphur with other chalcogens in peptides and proteins. *Journal of Peptide Science*. 2005; 2:187–214.
- Unrine JM, Jackson BP, Hopkins WA. Selenomethionine biotransformation and incorporation into proteins along a simulated terrestrial and food chain. *Environmental Science and Technology*. 2007;41:3601–3606.
- U.S. National Library of Medicine (NLM) - National Institute of Health (NIH). *Medline Plus*. 2009;3–10.
- Carvalho KM, Gallardo MT, Williams R, Benson R, Martin DF. Effects of selenium supplementation on four agricultural crops. *J. Agric. Food Chem*. 2003;51:704–709.
- Shao S, Zheng B. The biogeochemistry of selenium in Sunan Grassland, Gansu, North West China, cast doubt on the belief that Marco Polo reported selenosis for the first time in history. *Environmental and Geochemical Health*. 2000;11–18.
- Xue T, Hartikainen H, Piironen V. Antioxidative and growth – promoting effect of selenium on senescing lettuce plant and soil. 2001;237:55–61.
- Buchman M. Screening quick reference tables, national oceanic and atmospheric administration (NOAA), Seattle WA; 2006. Available:http://responserestoration.naa.gov/bookshelf/122_squirtcard.pdf
- Muhammad-Lawal A, Omotesho OA. Cereals and farming households' food security in Kwara State, Nigeria. *Agricultural Journal*. 2008;3:235–240. Available:<http://medwelljournals.com/abstract/?doi=aj.2008.235.240>
- Longman School Atlas. Dept of Geography, Benue State University, Makurdi, Nigeria. 2003;1–8.
- United States Environmental Protection Agency, Recommendations on maximum intake level of selenium. In: selenium paper prepared for consideration by export group on vitamins and minerals EVM/99/171; 2001.
- Raisbeck MF. Selenosis. *veterinary clinics of north-America: Food Animal Practice*. 2000;16:465–480.
- Abulude F, Ogunkoya M, Orojo T. Selenium in Nigerian foods, *electronic Journal of Polish Agricultural Universities*. 2006;9(3):06. Available:<http://www.ejpau.media.pl/volume9/issue3/abs-06.html>
- WHO/FAO/IAEA, *Trace Elements in Human Nutrition and Health*. Geneva. World Health Organization. 1996;6–10.

19. Rayman M. The important of selenium to human health, The lancet. 2008;356:233–241.
20. Nordic Group, Risk Evaluation of Essential Trace Elements. Essential Versus Toxic levels of Intake Nordic Council of Ministers, Nord; 1995.
21. Food Standard Australia New Zealand. A Joint Australia New Zealand Food Standards code. 2002;2:18–187.

© 2019 Zarmai et al.; This is an Open Access article distributed under the terms of the Creative Commons Attribution License (<http://creativecommons.org/licenses/by/4.0>), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

Peer-review history:
The peer review history for this paper can be accessed here:
<http://www.sdiarticle3.com/review-history/36506>