Selenium contents of common cereal and legume staples in Central Nigeria

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Abstract

The selenium contents of three selected cereals (maize, millet and sorghum) and four selected legumes (soybeams, 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 (μg/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 ± 18.9 μg/kg), followed by ground nuts (66.5 ± 15.4 μg/kg); the contents in soybeans (35.7 ± 9.3 μg/kg) and white beans (34.7 ± 7.2 μg/kg) were comparable. While 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 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.

Keywords: Selenium, Accumulator, Staple foods, Central Nigeria, HG-AAS.

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.

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 Figure 1) in January, 2012. Central Nigeria is an agricultural zone that produces more of these cerals 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.

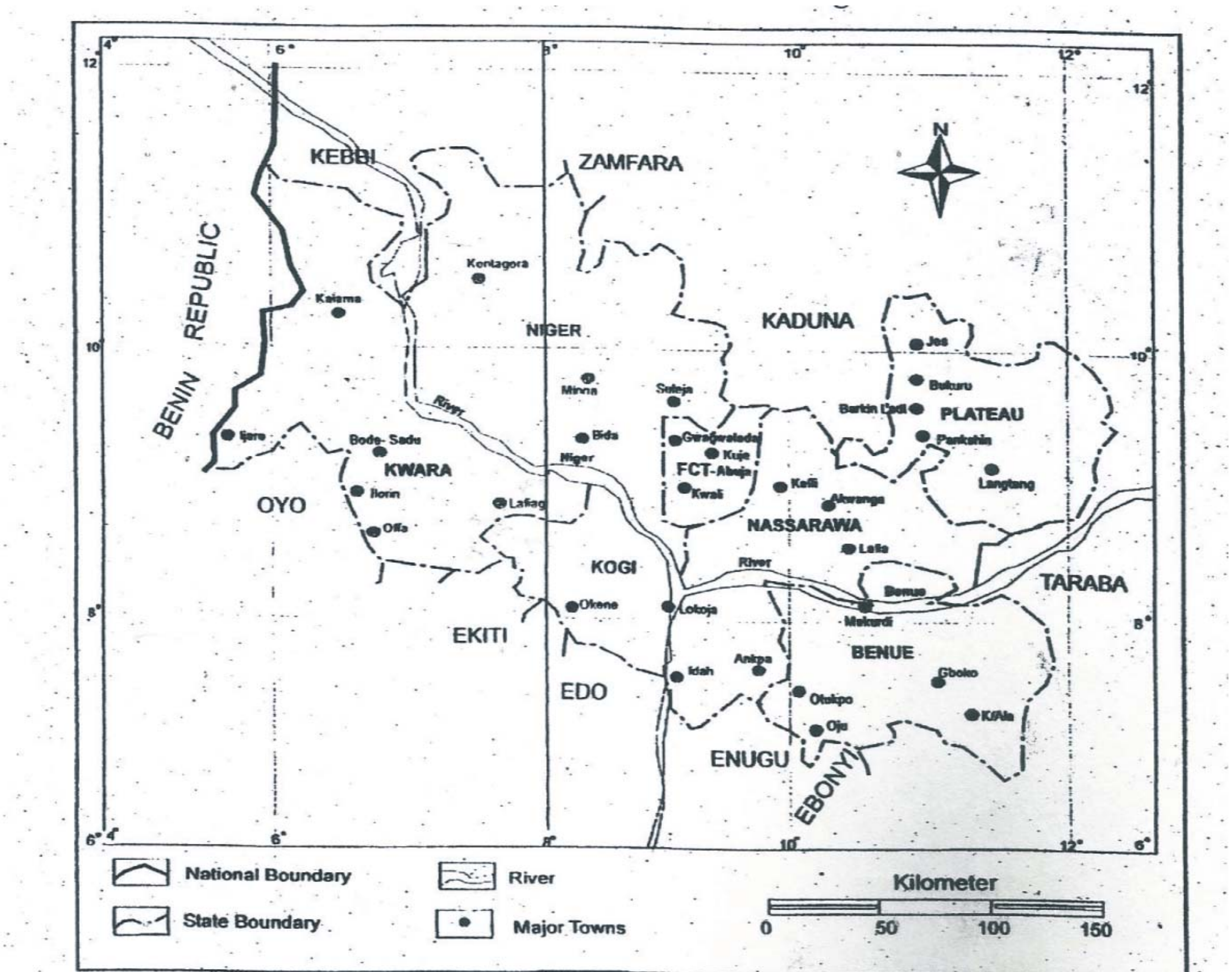

Fig. 1: Map of Central Nigeria showing Major Towns
Source: Longman School Atlas, 2003

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_20_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).

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. **Figures 2 and 3** shows the selenium contents in the selected cereal and legume staple crops respectively, along the sampling areas in the Central Nigeria.

Table 1: Mean selenium contents (μg/kg) of some common cereals and legumes samples.

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

Selenium contents of maize samples ranged from 0.01-392 μg/kg with Bida sample having the highest (392 μg/kg) while Otukpo, Idah and Jos samples having below detection limit (< 1.00 μg/kg) with the mean of 82.2 ± 27.7 μg/kg. In millet samples this varied between 0.01 – 172 μg/kg with Lafia sample containing the highest (172 μg/kg) while Bida sample having below detection limit (< 1.00 μg/kg) with the mean of 57.8 ± 12.2 μg/kg. Selenium contents of sorghum ranged from 0.01 – 101 μg/kg with Lokoja sample having the highest (101 μg/kg) while Keffi and Idah samples containing below detection limit (< 1.00 μg/kg) with the mean of 38.6 ± 7.9 μg/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 (μg/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 (μg/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 figure 3, the Se contents of soybeans samples in Central Nigeria ranged from 0.01 - 92.6 µg/kg with Lafia sample containing the highest (92.6 µg/kg) while Abuja, Idah and Lafiagi samples containing below the detection limit (< 1.00 µg/kg) of the instrument with the mean of 35.7 ± 9.3 µg/kg. Selenium contents obtained from ground nuts samples varied from 0.01 - 211 µg/kg with Bida sample having the highest (211 µg/kg) while Minna and Jos samples having below detection limit (< 1.00 µg/kg) with the mean of 66.5 ± 15.4 µg/kg. Selenium contents of white beans ranged between 0.01- 68.2 µg/kg with Ilorin sample containing the highest (68.2 µg/kg) while Keffi, Otukpo and Idah samples having below detection limit (< 1.00 µg/kg) with the mean of 34.7± 7.2 µg/kg. Selenium contents obtained from brown beans varied from 0.01 – 226 µg/kg with Lafia sample containing the highest (226 µg/kg) while Makurdi, Otukpo and Jos samples having below detection limit (<1.00 µg/kg) with the mean of 82.5± 18.9 µg/kg. The mean results of legume staples analyzed indicated that brown beans has the highest selenium contents (82.5 µg/kg), followed by ground nuts (66.5 µg/kg), then soybeans (35.7 µg/kg) and white beans the least (34.7 µg/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].

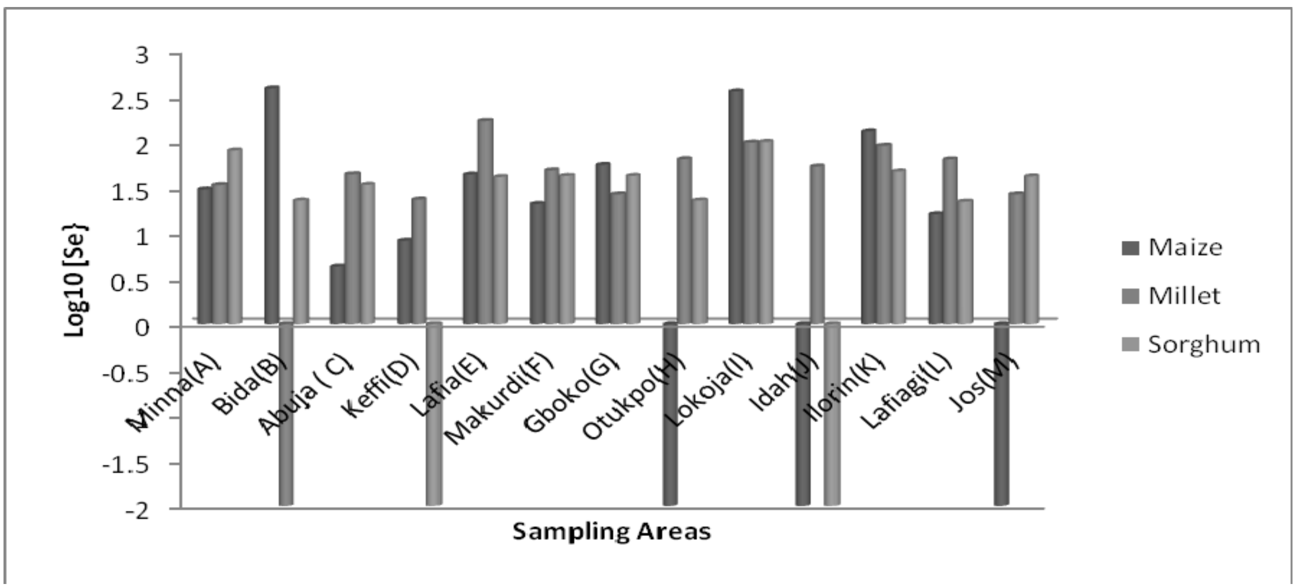

Figure 2: Selenium contents (µg/kg; log values) of some common cereal staples.

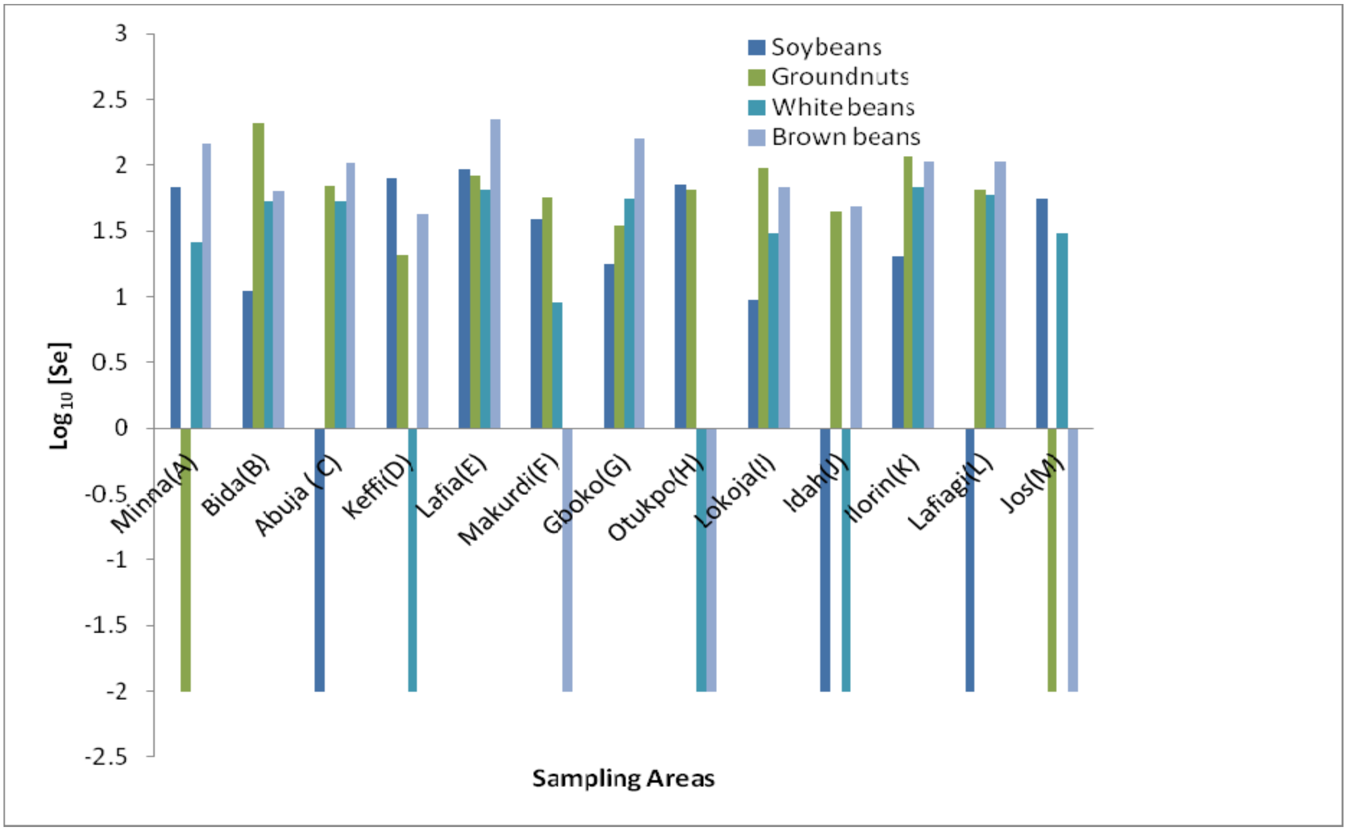

Figure 3: Selenium contents (μg/kg; log values) of some common legume staples.

Figures 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 el.* [11] reported the following Se contents (μg/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.

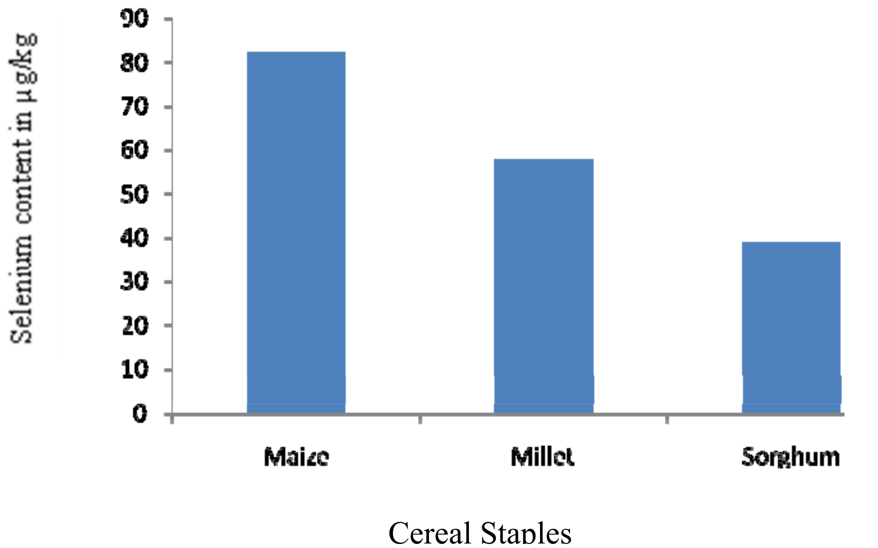

Figure 4: Mean selenium contents (µg/kg) of cereal staples using HG - AAS

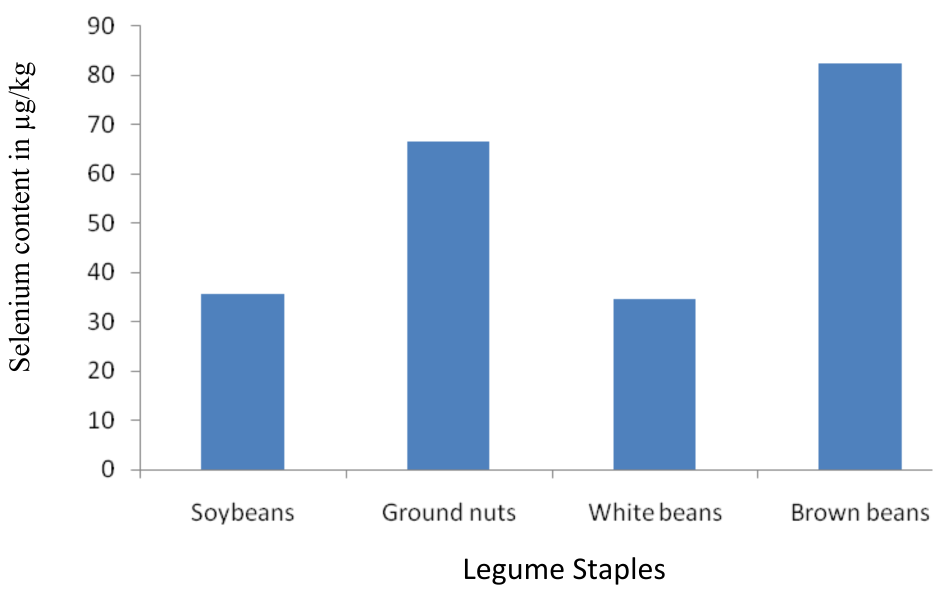

Figure 5: Mean selenium contents (µg/kg) in legume staples using HG-AAS

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 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.

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.

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