

1 **Selenium contents of common cereal and legume staples in Central Nigeria**

2

3 **Abstract**

4 The selenium contents of three selected cereals (maize, millet and sorghum) and four selected
5 legumes (soybeans, groundnuts, white and brown beans) grown and consumed in Central
6 Nigeria was determined using hydride generation–atomic absorption spectrophotometry (HG–
7 AAS). Results of the analysis showed that mean concentrations ($\mu\text{g}/\text{kg}$) of selenium in the
8 cereals were 82.2 ± 27.7 ; 57.8 ± 12.2 and 38.6 ± 7.9 for maize, millet and sorghum, respectively.
9 Similarly, analytical results showed that among the legumes, brown beans contained the highest
10 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
11 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.
12 While the mean values for selenium contents obtained in this work are generally higher than
13 literature values for similar foodstuff, most of the values lie within the limit referred to as lower
14 and safe upper reference nutrient intake. The differences could be due to the total selenium
15 concentration and its bioavailability in the soils on which these crops are grown. The trend of
16 selenium contents in the cereal and legume staples was as follows: maize > brown beans >
17 groundnuts > millet > sorghum > soybeans > white beans.

18 **Keywords:** Selenium, Cereals, Legumes, Staples, Central Nigeria, HG-AAS.

19 **Introduction**

20 Plants and animals assimilate selenium (Se) to varying degrees. Evidence for whether Se is
21 essential for plant and crop health is equivocal, but plants can be divided into three groups: Se –
22 accumulators, Se – indicators (or secondary Se – accumulators) and non-accumulators. Non –

23 accumulators rarely assimilate more than 100 mgkg^{-1} Se (dry weight), where as Se accumulators
24 can contain up to $40,000 \text{ mgkg}^{-1}$ Se (dry weight) when grown in seleniferous environment [1]. In
25 non-accumulator cereal crops (such as wheat, oats, rye and barley are non-accumulators) the
26 grain and roots often contain similar amounts of the element whereas concentration in the stems
27 and leaves are lower [2, 3]. The only Se accumulator plant regularly used as a food source is the
28 tree *Bertholletia excelsa*, which produces Brazil nut, which are known to be richest source of
29 dietary Se. However, some common crop species, for example *Brassica* species (rape seed,
30 calabrese broccoli, cabbage) and *Allium* species (garlic, onions, leeks and wild leeks), are
31 secondary Se-accumulators.

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

45 In most cases, food forms the major source of selenium for humans as its concentration in water
46 and air are extremely low [9]. The concentration of selenium in food stuffs depends upon the
47 selenium concentration of the soil on which the food was grown [10]. Brazil nuts which contains
48 554 $\mu\text{g}/\text{kg}$ selenium is the richest staple food in the world and forage crops containing less than
49 40 $\mu\text{g}/\text{kg}$ selenium are generally associated with deficiency in grazing animals [11]. Selenium
50 concentration of most soils is very low ranging from 0.01 to 2 mg/kg but high concentration of
51 up to 1200 mg/kg have also been reported in some seleniferous areas [12]. The estimated lower
52 and safe upper reference nutrient intake values have been documented [11].

53 Cereals and legumes based products are the most important source of food and provide the major
54 source of energy and protein for a majority of people in developing countries, including Nigeria
55 [13]. Considering the health implications of a selenium-deficient diet in a population, we decided
56 to investigate the selenium contents of some of the common selected cereals and legumes
57 grown/consumed in Central Nigeria, since there is little or no information available on their
58 selenium contents. This research is significant in that, it will shade light on which of the staples
59 contain higher contents of selenium.

60 **Materials and Methods**

61 Sample of cereals (maize, millet and sorghum) and legumes (soybeans, groundnuts, white and
62 brown beans) were collected in Minna, Bida, Abuja, Keffi, Lafia, Makurdi, Gboko, Otukpo,
63 Lokoja, Idah, Ilorin, Lafiagi and Jos in Central Nigeria (see Figure 1) in January, 2012. The
64 samples were packed in well labeled polyethylene bags noting the food types and area of
65 collection. Samples were transported to laboratory and cleaned to remove empty, diseased seeds
66 and debris.

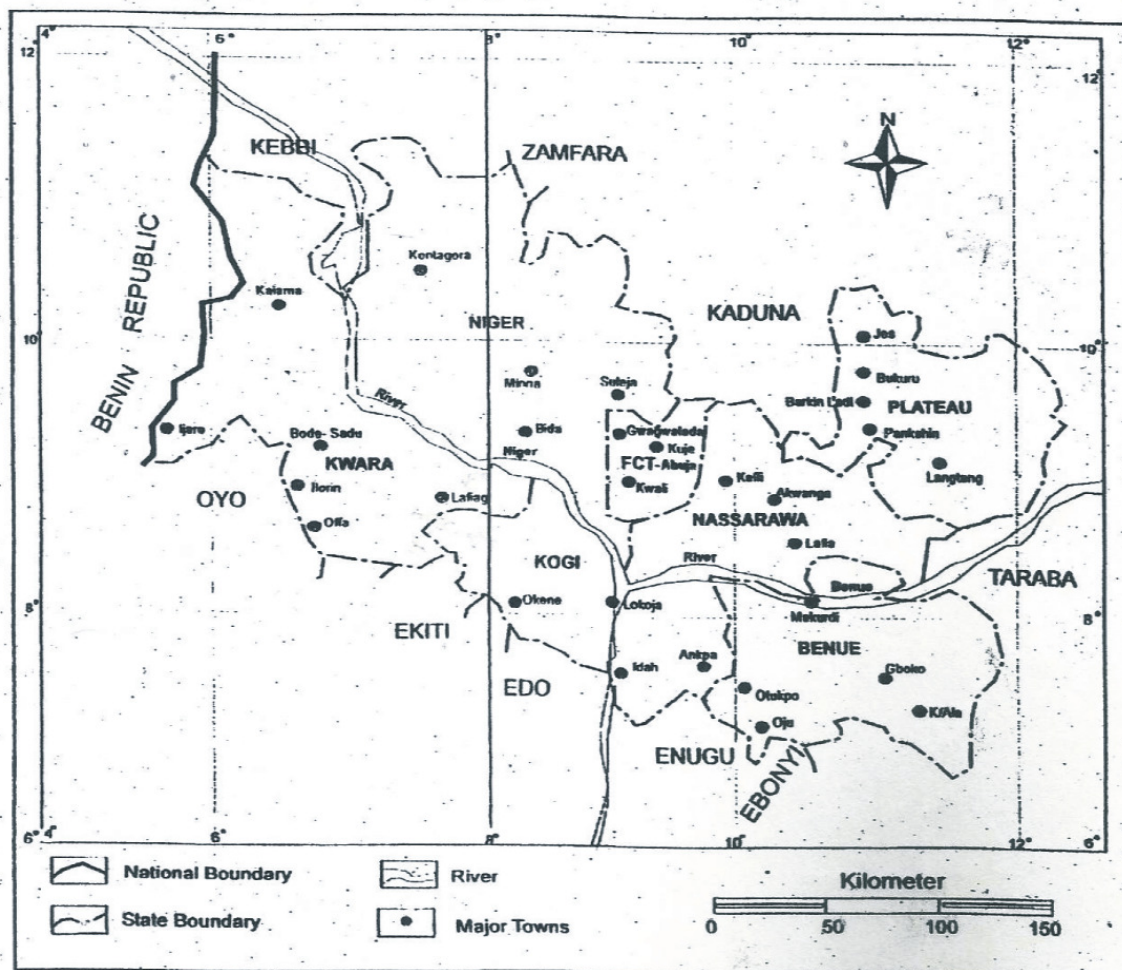


Fig. 1: Map of Central Nigeria showing Major Towns
 Source: Longman School Atlas, 2003

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68 Samples were washed with distilled water and allowed to dry. Each sample was oven dried at
 69 105 °C to constant weight for about 2 – 3 hours. The oven dried samples were crushed in a
 70 ceramic mortar and pestle, sieved with the mesh of aperture 2 mm and stored in moisture
 71 resistance plastic bottles [15]. One gram of each crushed samples was weighed into a 30 mL
 72 crucible with lid. Exactly 10 mL of Concentrated HNO₃ (70.5 – 96 % AR) was then added and
 73 the mixture placed on hot plate maintained at 60 °C for 30 minutes, after which it was brought
 74 down and allowed to cool. Subsequently, 30mL of H₂O₂ (30 %) was added and the digestion was
 75 continued at 120 °C for 1h. After cooling the sample, it was diluted with de-ionized water and

76 finally filtered. The filtrate was diluted to a total volume of 100 mL volumetric flask. The
 77 filtrates were stored in plastic sample bottles in fridge prior to analysis. A reagent blank sample
 78 was prepared similarly to account for possible contamination. Selenium contents in the digest
 79 was determined using hydride generator (GBC – HG – 3000) – atomic absorption
 80 spectrophotometer (GBC – Avanta) at Fugro Nigeria limited, Port-Harcourt. Determinations
 81 were in duplicate. Statistical analysis was performed using SYSTAT version 16.0 (SPSS, USA).

82 **Results and Discussion**

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

91 **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
	Maize (<i>Zea mays</i>)	13	82.2 \pm 27.7	0.01	392
Cereals	Millet (<i>Bajra pennisetum americanum</i>)	13	57.8 \pm 12.2	0.01	172

	Sorghum (<i>sorghum bicolor</i>)	13	38.6±7.9	0.01	101
	Soybeans (<i>Glycine max</i>)	13	35.7±9.3	0.01	92.6
Legumes	Groundnuts (<i>Arachis hypogea</i>)	13	66.5±15.4	0.01	211
	White beans (<i>Vigna unguiculata</i>)	13	34.7±7.2	0.01	68.2
	Brown beans (<i>Vigna unguiculata</i>)	13	82.5±18.9	0.01	226

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93 Selenium contents of maize samples ranged from 0.01-392 $\mu\text{g}/\text{kg}$ with Bida sample having the
 94 highest (392 $\mu\text{g}/\text{kg}$) while Otukpo, Idah and Jos samples having below detection limit (< 1.00
 95 $\mu\text{g}/\text{kg}$) with the mean of $82.2 \pm 27.7 \mu\text{g}/\text{kg}$. In millet samples this varied between 0.01 – 172
 96 $\mu\text{g}/\text{kg}$ with Lafia sample containing the highest (172 $\mu\text{g}/\text{kg}$) while Bida sample having below
 97 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
 98 ranged from 0.01 – 101 $\mu\text{g}/\text{kg}$ with Lokoja sample having the highest (101 $\mu\text{g}/\text{kg}$) while Keffi
 99 and Idah samples containing below detection limit ($< 1.00 \mu\text{g}/\text{kg}$) with the mean of 38.6 ± 7.9
 100 $\mu\text{g}/\text{kg}$.

101 Statistical analysis of variance between and within the data of cereal crops (maize, millet and
 102 sorghum) revealed that there was no significant difference ($P > 0.05$) in selenium contents
 103 ($\mu\text{g}/\text{kg}$) determined from maize, millet and sorghum in Central Nigeria. Multiple mean
 104 comparisons using Tukey Honest Significant Difference (HSD) test showed that there was no
 105 significant difference ($P > 0.05$) in selenium contents ($\mu\text{g}/\text{kg}$) in cereals determined.
 106 Homogeneous subset test revealed that there was correlation ($\alpha = 0.05$) between maize, millet

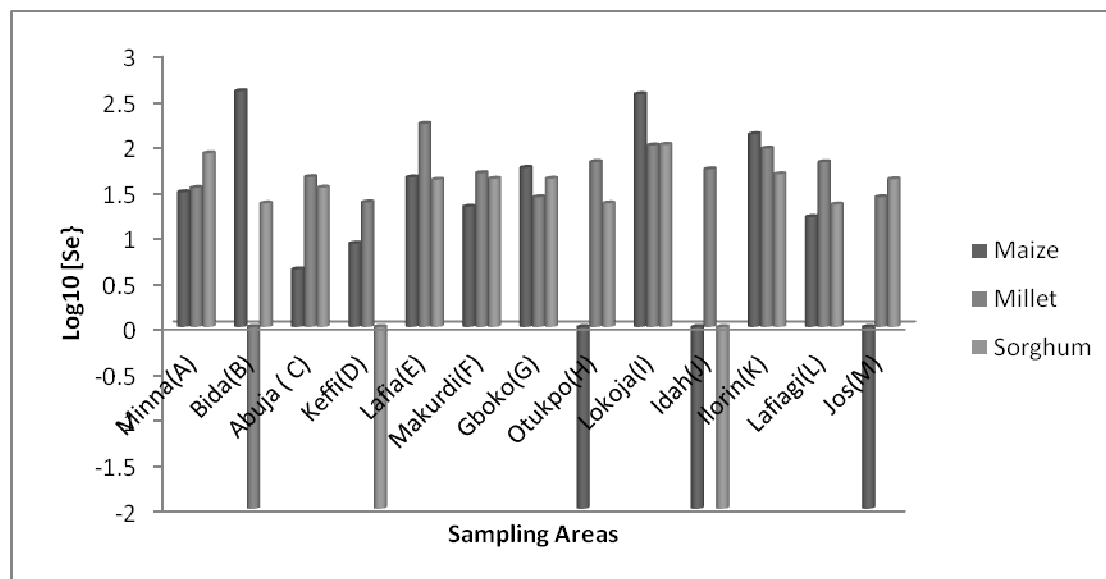
107 and sorghum. The result of this analysis is further confirmation that cereal staples are non-
108 selenium accumulators [5].

109 As presented in figure 3, the Se contents of soybeans samples in Central Nigeria ranged from
110 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
111 Lafiagi samples containing below the detection limit ($< 1.00 \mu\text{g}/\text{kg}$) of the instrument with the
112 mean of $35.7 \pm 9.3 \mu\text{g}/\text{kg}$. Selenium contents obtained from ground nuts samples varied from
113 0.01 - 211 $\mu\text{g}/\text{kg}$ with Bida sample having the highest (211 $\mu\text{g}/\text{kg}$) while Minna and Jos
114 samples having below detection limit ($< 1.00 \mu\text{g}/\text{kg}$) with the mean of $66.5 \pm 15.4 \mu\text{g}/\text{kg}$.
115 Selenium contents of white beans ranged between 0.01- 68.2 $\mu\text{g}/\text{kg}$ with Ilorin sample containing
116 the highest (68.2 $\mu\text{g}/\text{kg}$) while Keffi, Otukpo and Idah samples having below detection limit ($<$
117 $1.00 \mu\text{g}/\text{kg}$) with the mean of $34.7 \pm 7.2 \mu\text{g}/\text{kg}$. Selenium contents obtained from brown beans
118 varied from 0.01 – 226 $\mu\text{g}/\text{kg}$ with Lafia sample containing the highest (226 $\mu\text{g}/\text{kg}$) while
119 Makurdi, Otukpo and Jos samples having below detection limit ($<1.00 \mu\text{g}/\text{kg}$) with the mean
120 of $82.5 \pm 18.9 \mu\text{g}/\text{kg}$. The mean results of legume staples analyzed indicated that brown beans has
121 the highest selenium contents (82.5 $\mu\text{g}/\text{kg}$), followed by ground nuts (66.5 $\mu\text{g}/\text{kg}$), then soybeans
122 (35.7 $\mu\text{g}/\text{kg}$) and white beans the least (34.7 $\mu\text{g}/\text{kg}$).

123
124 Analysis of variance between and within the data of legumes (Soybeans, ground nuts, white
125 beans and brown beans) showed that there was no significant difference ($P > 0.05$) in Selenium
126 contents between brown beans, ground nuts, soybeans and white beans. Multiple comparisons
127 using Tukey Honest Significant Difference (HSD) test revealed that there was no significant
128 difference ($P > 0.05$) in selenium content in legumes determined. Homogeneous subset test
129 showed that there was correlation between soybeans, ground nuts, white beans, and brown beans

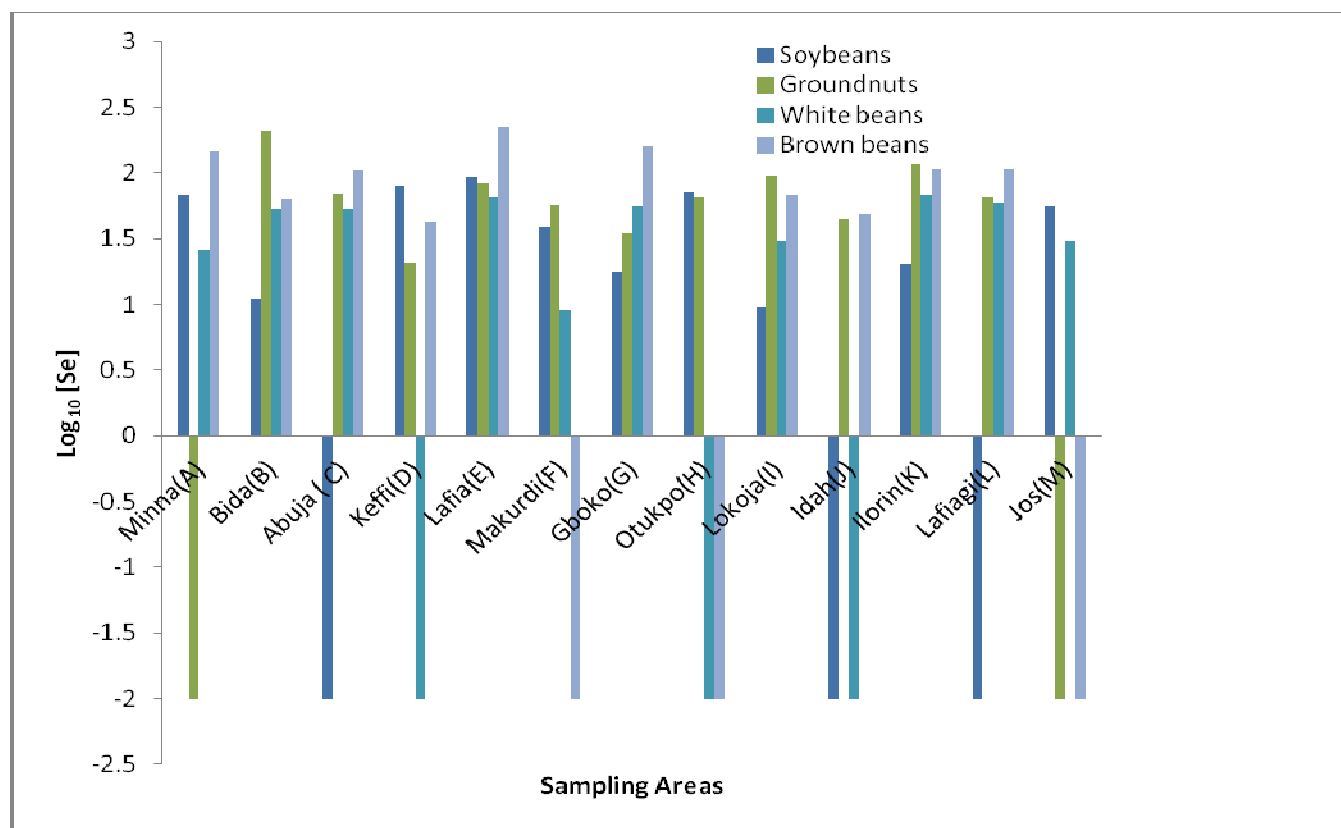
130 ($\alpha = 0.05$). The results of this analysis are clear confirmation that legume staples are also non-
 131 selenium accumulators [16].

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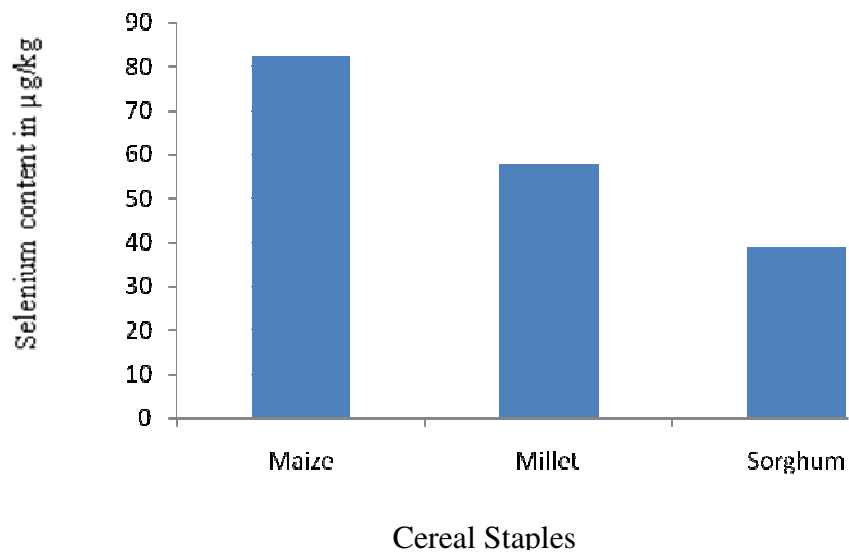
134 **Figure 2:** Selenium contents ($\mu\text{g}/\text{kg}$; log values) of some common cereal staples from different
 135 sampling areas in Central Nigeria



136

137 **Figure 3:** Selenium contents ($\mu\text{g}/\text{kg}$; log values) of some common legume staples from different
 138 sampling areas in Central Nigeria

139 **Figures 4 and 5** are bar charts of the mean Se contents of cereals and legume staples determined
 140 in this work. The values we obtained were within the range of literature values. Xue *et al.* [11]
 141 reported the following Se contents ($\mu\text{g}/\text{kg}$) for foods in the USA to be: canned tuna 63, cod 32,
 142 beef 35, brown rice 10, white rice 12 and chicken 20. IMFNB [5] reported the range of staple
 143 foods between 40 – 450 $\mu\text{g}/\text{kg}$. Abulude *et al.* [17] reported also very high mean of selenium
 144 contents (millet 5 ± 3.4 mg/kg, rice 5 ± 2.5 mg/kg, white beans 10 ± 4.5 mg/kg, melon 5 ± 3.7
 145 mg/kg, plantain less than 1 ± 8.4 mg/kg) in the Western part of Nigeria using AAS.



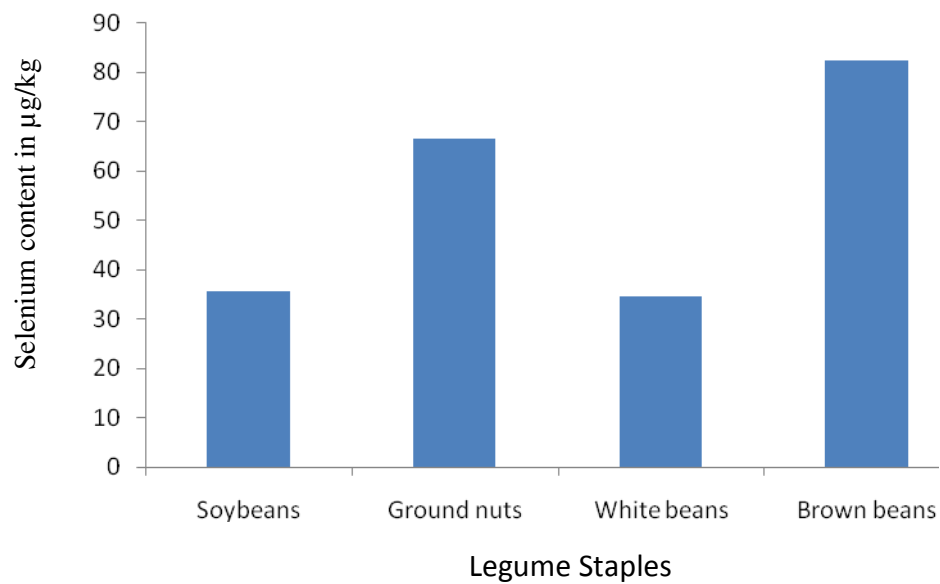
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Figure 4: Mean selenium contents (µg/kg) of cereal staples using HG - AAS

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


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153 The differences in the selenium contents of the cereal and legume staples we selected and those
154 in literature may basically be due to the total selenium concentration and its bioavailability in the
155 soil where these are grown [4, 12, 16]. Variations in the results of this analysis could also be
156 attributed to the presence or absence of anthropogenic activities on the soils such as application
157 of phosphate and sulphate fertilizers, pigments in glass and ceramic manufacture, antifungal
158 agent in pharmaceuticals, fossil fuel combustion and light- sensitive photoconductor layer in
159 photocopiers. In addition, as we eat a varied diet obtained from different geographical areas, it
160 is unlikely that selenium deficiency in the soil in few locations will cause selenium deficient in
161 Central Nigerians' diet. Everybody consumption will vary about the determined mean,
162 depending on the amount of protein in the diet and particularly the amount of selenium rich
163 foods which are eaten [8, 18].

164 There have been several quoted maximum intakes of selenium: WHO/FAO/IAEA [19] quoted
165 400 μg Se/day, IMFNB [5] recommended 450 μg Se/day, Nordic Group [20] considered an
166 intake of 280 – 350 μg Se/day and Food Standard Australia New Zealand (FSANZ) [21] reported
167 Australian RDI to be 85 μg Se/ day.

168 **Conclusion**

169 Analysis of Se contents shows one of the samples of cereals and legume staples indicates that
170 most samples contained relatively large quantity of the element while few others had below the
171 detection limit. The level of Se contents in these cereals and legumes studied was a clear
172 manifestation of geographical origin, bioavailability of the Se in the soil and anthropogenic
173 activities. This work has shown that better food sources of selenium were maize, brown beans,

174 groundnuts and millet. Sorghum, soybeans and white beans contained some reasonable contents
175 of selenium and it is not likely that selenium deficiency occurs in Central Nigeria. 

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