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Mineral constituents of roasted cashew nuts (*Anacardium occidentale L.*) from Southeastern Nigeria

Nnorom C. Innocent, Ewuzie Ugochukwu
Environmental Chemistry Unit, Department of Pure and Industrial Chemistry, Abia State University, Uturu, Nigeria.

Abstract : *This paper presents the results of the determination of Ca, Cr, Cu, Fe, K, Mg, Mn, Na, Ni, and Zn in 30 samples of roasted cashew nuts from six towns in Southeastern Nigeria. The elements were determined by flame atomic absorption spectroscopy with background correction after ashing of the nuts at 450 °C and mineralizing with acids. The results (mg/kg; dry matter) showed that K (overall mean) occurred at 6200±130, Mg at 2900±110, Na at 2600±180, Ca at 360±40, Zn at 71±6, Fe at 69±6, Cu at 23±2, Mn at 21±2, Ni at 0.25±0.07 and Cr at 0.078±0.036. Consumption of cashew nuts in the two retail weights of approximately 35 and 79 g will provide (mg/day): 217–489 K, 102–229 Mg, 91–205 Na, 13–28 Ca, 2.5–5.6 Zn, 2.4–5.5 Fe, 0.8–1.8 Cu and 0.7–1.7 Mn. Compared to the Reference Daily Intake, these values will amount (%) to 40-90 for Cu, 35-85 for Mn and 13-31 for Fe. PCA analysis revealed interrelationships among the metals and suggested that the metals were of natural sources. Roasted cashew nuts would therefore serve as a dietary source of essential elements and pose no toxicological health risks.*
Keywords: *Foods, micronutrients, Nigeria, roasted cashew nut, trace elements*

I. Introduction

The cashew tree, *Anacardium occidentale L.*, belongs to the *Anacardiaceae* family and is a versatile tree nut [1, 2] that is native to Brazil. The ‘‘cashew fruit’’ comprises the cashew ‘‘apple’’, a pseudo-fruit formed by an enlarged peduncle, and the true fruit, a kidney-shaped (reniform) achene about 3 cm long with a hard grey-green pericarp [3, 4]. This plant nowadays is cultivated in tropical regions worldwide. Cashew was introduced in Nigeria in the 15th/16th century by the Portuguese explorers [5, 6] and it was mainly used in afforestation schemes for the control of erosion in the former Eastern Nigeria. Commercial cashew plantations started in Nigeria in the early 1950s with the establishment of first commercial plantations [7]. Presently, Nigeria ranks among the largest producers of cashew nuts together with India with 650,000 and 613,000 metric tons, respectively, and other major producers are Côte d'Ivoire, Vietnam, Indonesia, Philippines, Brazil, Guinea-Bissau, Tanzania and Benin with total output of 2, 757, 598 metric tons in 2010 [8]. The average yield of nuts of a mature tree is in the range of 7 to 11 kg per annum. Although the cashew tree is capable of living for 50 to 60 years, most trees produce nuts for about 15 to 20 years [2].

Around the world, and in Nigeria in particular, the name ‘Cashew’ refers to both the ‘‘apple’’ and the kidney-shaped, nutlike seed of the cashew tree. The cashew apple is well consumed during the season while the nut is roasted and consumed in large quantities in Nigeria all year round. Cashew nuts are roasted over open fires or in red hot charcoal in most Nigerian rural communities, allowed to cool before they are cracked and consumed. Currently, 75 to 80% of cashew nuts produced in Nigeria are exported, as only very few companies are involved in local processing of the produce [7, 9].

Data on the elemental composition of food and feedstuff are of great importance because of their benefits (nutritional value) as well as risk (estimation of toxic exposure) [10, 11, 12]. Metallic elements including Zn, Fe, Mg, Mn, Co and Cr (III) play important roles in different human metabolism and are therefore nutrient elements for human health while Pb, Cd and Hg and Cr (VI) are known to be toxic to human [13, 14].

Several studies have shown nuts to be a rich source of nutrients, mainly protein, fat, vitamins, as well as minerals such as P, K, Mg, Fe [15, 16]. Consequently nuts have been recognized as important sources of some essential elements (e.g. B, Se, Cu, Zn, Fe and Mn) in human nutrition [10, 17]. Considering the high production and consumption rates and the importance of understanding the mineral composition of roasted cashew nuts consumed in Nigeria, this present paper reports the results of validated instrumental determination of the mineral composition of roasted cashew nuts. The outcome of this research provides information on the micronutrient contents of roasted cashew nuts and adds to the existing database of element composition of foods and foodstuff in Nigeria.

II. Materials and method

2.1 Sampling

Roasted cashew nuts are considered important snack in Nigeria. They are marketed in wraps of ₦50 or ₦100 ($1= ₦156). Cashew nuts from six different towns in Abia State, Southeastern Nigeria (namely: Ubakala, Omoba, Ntigha, Uturu, Uzuakoli and Obehie) were sampled and studied. For each of the six towns, three wraps were purchased at five different locations and pooled together to give five composite samples per town. A total of thirty (30) samples were packed in brand new sealable polyethylene bags and taken to the laboratory. The cashew nuts were purchased as products, processed (roasted), packaged and on sale from hawkers and vendors in motor loading bays, streets, institutions or road sides.

2.2 Elemental analysis

In the laboratory, the samples were crushed in porcelain mortar, homogenized, and dried to constant weight at 105 °C in an oven for 6 h, and allowed to cool. It was then sifted through 2 mm sieve. 1 g of sample was ashed in a muffle furnace at an oven temperature of 450 °C for 5 h and quantitatively transferred into a 250 ml conical flask. Next, 10 ml of the digestion acid mixture (ratio 1:2:2 of perchloric, nitric and sulphuric acids) was added into the ash and gently heated on a hot plate in a fume hood until a white fume was observed which signified that digestion was complete. The digest was allowed to cool and 20 ml of distilled water was added to bring the minerals into solution and subsequently filtered using ashless Whatman filter paper into a 100 ml calibrated volumetric flask and made up to mark with distilled water. The digests were analyzed for Ca, Cr, Cu, Fe, K, Mg, Mn, Na, Ni, and Zn using Buck 200A (Buck Scientific; Norwalk, CT, USA) flame atomic absorption spectrometer with background correction.

The elements, Ba, Pb, Cd and V were also determined and were found to be below the detection limits of 0.001 mg/kg dry matter (dm). This observation for Ba, Pb, Cd and V compares well with results reported in literature for cashew nuts (0.0005 mg/kg for Cd; 0.002–0.3 mg/kg for Pb and 0.001 mg/kg for V) by Preedy *et* al. [18]. Hence the results for these elements were not presented

2.3 Quality assurance

Appropriate quality assurance procedures and precautions were carried out to ensure the reliability of the results. All chemicals used were of analytical grade: H_2SO_4 (98%, BDH Laboratory Supplies, Poole, England); HNO_3 (69%, BDH Laboratory Supplies, Poole, England); $HClO_4$ (70%, Sigma-Aldrich, St. Louis, USA). To eliminate the risk of contamination during the experiments, all plastic and glassware were carefully cleaned by washing, rinsing severally with tap water, and then soaking in 5% HNO_3 solution for a minimum of 24 h. They were rinsed severally with deionized water before use. Reagent blank determinations were used to correct the instrument readings. The accuracy of the analytical method was calculated by analyzing a certified reference material (CRM: Accu Standards, New Haven Connecticut, USA). Also spike recovery was conducted on some of the samples. Detection limit is defined as the concentration corresponding to three times the standard deviation of seven blanks. Recoveries for the CRM varied from 96–102% and for the spiking study, from 97–101% (Tables 1 and 2 respectively).

Table 1. Elements concentration in certified reference materials (Accu standards USA)

Element	Certified value (mg/L)	Our value (mg/L)[b]	Recovery (%)
Ca	3.0 ± 0.2	2.89 ± 0.16[a]	96
Cd	0.375 ± 0.167	0.372 ± 0.124	99
Cu	0.75 ± 0.35	0.734 ± 0.332	98
K	12.5 ± 3.53	12.24 ± 3.31	98
Na	7.5 ± 3.5	7.56 ± 3.51	101
Pb	0.375 ± 0.177	0.384 ± 0.174	102
Zn	0.88 ± 0.24	0.89 ± 0.32	101

[a] Mean ± standard deviation [b]n=3

Table 2. Spiked recovery of some of the metals (n =3)

Elements	Spiked concentration (mg/kg)	Recovered concentration (mg/kg)	Recovery (%)
Fe	23.45 ± 0.06 [a]	25.98 ± 1.52	98
Cu	20.78 ± 0.17	20.56 ± 0.41	99
Zn	66.3 ± 0.1	64.2 ± 1.9	97
K	5770 ± 1	5668 ± 7	98
Na	2902 ± 8	2920 ± 3	101
Mg	2558 ± 1	2580 ± 2	101

[a] Mean ± standard deviation

2.4 Statistical analysis

Statistical analysis of data was carried out using SPSS 16.0 for windows (SPSS Inc., Polar Engineering and Consulting 2007) and Excel 2007 statistical package programs. One-way ANOVA was employed to find the significant differences of metallic elements (or trace metal) concentrations in cashew nuts with respect to sampling areas. The significance was set at $p < 0.05$. Also, two–tailed correlation analyses of metallic constituents of the samples analyzed, depending on sites were conducted. Principal component analysis (PCA) used in this study was aimed at visualizing the principal attributes of the analytical data and distribution of elements' concentrations in cashew nuts, which will be difficult to identify with tables alone. It generates a new set of values of linearly uncorrelated variables called the principal components (PCs) through linear transformation of a set of observations of perhaps correlated variables. The aim of Varimax normalized rotation is to maximize the variances of normalized factor loadings across variables for each factor [19].

2.5 Estimation of metals intake

In the regions studied, roasted cashew nuts are marketed in two different prices to meet the needs of various income earners: ₦100 (average weight of 79.005±0.090 g) and ₦50 (average weight of 35.011±0.028 g). Survey conducted indicated that, on the average, an individual consumes a minimum of ₦50 and a maximum of ₦100 worth of roasted cashew nuts daily. Therefore, the daily intakes of Ca, Cr, Cu, Fe, K, Mg, Mn, Na, Ni, and Zn from cashew nuts were estimated based on this range (consumption of 35 – 75 g) using the mean results of this study. The metals intake was compared with Reference Daily Intakes (RDI) for metals recommended by the FDA [20], FAO/WHO [21], USDA [22] and the Institute of Medicine [23].

III. Results and discussion

3.1 Elemental composition of cashew nuts

The mean results (mg/kg dry weight) for Ca, Cr, Cu, Fe, K, Mg, Mn, Na, Ni, and Zn contents of cashew nuts and the combined data for all sampling areas were presented in Table 3. Among the major elements examined, the element K was the most abundant with overall mean concentration of 6200±130 mg/kg (range 5400–7100) and this was comparable with the available data of 6600±20 mg/kg dm and 7301±396 mg/kg dm reported by Preedy *et al*. [18] and Naozuka *et al.* [24] respectively. Potassium serves an electrolyte for maintaining normal fluid balance in cells and a delicate balance of this element is reported to prevent an increase in blood pressure and maintain normal cardiac rhythm [25]. Thus cashew nuts can serve as a good source of this essential nutrient.

The overall mean calcium content was 360±40 mg/kg, which ranged between 310±40 mg/kg for Obehie and 420±10 mg/kg for Uturu (Table 3). These values were higher than the overall mean of 242±30 mg/kg dm shown in the study by Naozuka *et al.* [22]. Calcium ion is known to be involved in and regulates the permeability and electrical properties of biological membranes. It plays essential roles in neuromuscular function, in many enzyme-mediated processes, blood clotting, and in providing rigidity to the skeleton via phosphate salts [26]. Its non-structural roles require the strict maintenance of ionized calcium concentration in tissue fluids at the expense of the skeleton if necessary, and it is therefore the skeleton which is at risk if the supply of Ca falls short of requirement [21].

The minimum and maximum Na contents of samples from this study were 2300 and 3000 mg/kg dm respectively. These Na concentrations were between 21 – 27 times the mean Na content reported in literature (110 ± 30 mg/kg dm) by Preedy *et al.* [18]. The amount of Na in a diet markedly affects the health and nutrition of the individual. Although Na is necessary to maintain balance in physical fluid systems and is also required for the operation of nerves and muscles, high-sodium diets are linked to a number of health problems including damage of the kidneys and increase in the possibilities of hypertension [26]. Methods of preparation of the nuts prior to the roasting processes could contribute to the high Na content of the investigated samples. For instance, the nuts are usually salted using common salt to meet the organoleptic requirements and acceptability of consumers.

Mean Mg content of cashew nuts in this study (2900±110 mg/kg) compared well with data available in literature. For instance, Naozuka *et al.* [24] and Preedy *et al.* [18] report mean Mg concentrations of 2794±267 and 2800±5 mg/kg dm respectively for cashew nuts. However, these values are lower than the mean value of 4100±100 mg/kg dm reported for Brazil nuts [18]. The importance of Mg has not only been depicted in its function in the skeleton, but also in muscles and soft tissues, such as a co-factor of many enzymes involved in energy metabolism, protein synthesis, RNA and DNA synthesis, and maintenance of the electrical potential of nerve tissues and cell membranes [26]. The element's dietary deficiency, which is sufficient to induce pathologic changes, is however rare [21].

Nickel toxicity at elevated levels is more prominent, but trace amounts may be beneficial as an activator of some enzyme systems [27, 28]; although its essential roles have not been totally proved in humans.

The mean Ni content of cashew nuts in this study was 0.25±0.07 mg/kg dm which is well below the values reported by Preedy *et al.* [18] for cashew nuts (3 mg/kg dm) and Brazil nuts (7±30 mg/kg dm).

The element Cr was not detected in cashews sampled from Omoba and Ntigha. Nevertheless, the overall range was from <0.001 to 0.14 mg/kg dm (Table 3). Reports indicate that Cr (III) is an essential element that helps the body use sugar, protein, and fat, while at the same time it (especially, Cr VI) is carcinogenic for organisms [29]. The low level of total Cr in cashew nuts from this study when compared with those reported by Preedy *et al.* [18] for cashew nut (0.01–0.3 mg/kg) and Brazil nuts (0.02–0.8 mg/kg) does not indicate health concern.

The overall mean Cu concentration of the present study (23±2 mg/kg) agreed with the reported values of 20, 19.1±0.1 and 21±20 mg/kg dm by Rodushkin *et al.* [15]; Nascimento *et al.* [17] and Preedy *et al.* [18] respectively, but is greater than the value of 6.1±0.5 mg/kg dm reported by Naozuka *et al.* [24]. Copper is essential for good health but very high intakes can cause adverse health problems such as liver and kidney damage [30]. Copper deficiency leads to hypochromic anemia, leucopenia and osteoporosis in children [31]. Roasted cashew nuts are therefore a good source of Cu to consumers of this tasty delicacy.

The significance of Fe in maintaining good health and well being has long been acknowledged by nutritionists. The mean Fe concentration of this study was 69±6 mg/kg dm and this was close to the values reported in the literature which ranged from 53.3 to 67 mg/kg dm for cashew nuts [15, 17, 18, 24] and from 22 to 37 mg/kg for Brazil nuts [15, 18]. It is recognized that adequate iron in a diet is very imperative for diminishing the incidence of anemia [32]. Fe deficiencies are often associated with anemia and, thus, diminish working capacity and impaired intellectual development [33].

The overall mean of Mn was 21±2 (range: 17–24) mg/kg dm (Table 3). Preedy *et al.* [18] reports a similar average content of 23±30 mg/kg dm, while a lower mean of 13±1 mg/kg dm, is reported in a study by Naozuka *et al.* [24]. The deficiency of Mn can produce severe skeletal and reproductive abnormalities in mammals, while high doses of Mn could produce adverse effects primarily on the lungs and on the brain [28]. Manganese plays a vital role in the control of diabetes [25], thus cashew nut will be a good source of Mn to cushion these abnormalities.

The results of Zn in roasted cashew nuts ranged between 58 and 81 mg/kg while the median is 59. The overall mean Zn concentration of this study (71±6 mg/kg) is higher than the values of (57±10 mg/kg) and (54±7 mg/kg) reported by Preedy *et al.* [18] and Naozuka *et al.* [24] respectively. Zn plays essential role as metalloenzymes and as a cofactor of large number of enzymes [20].

3.2 Relationship between metals studied

The result of one-way ANOVA showed that sampling areas significantly influenced the mean levels of metals in cashew nuts. The results of the correlation analyses are presented in Tables 1S, 2S and 3S (supporting tables). In Ubakala, minimum and maximum significant positive correlation existed for Mn-Ca ($r= 0.982$) and Cu-K ($r= 0.996$) respectively at $p= 0.01$, and in Zn-Ca ($r= 0.881$) and Zn-Na ($r= 0.956$) respectively at $p= 0.05$. Samples from Omoba only showed significant positive correlations in Ca-Mg ($r= 0.923$), Ca-Ni ($r= 0.938$), Na-Ni ($r= 0.946$), Na-Mg ($r= 0.986$) and Mg-Ni ($r= 0.964$). For cashew nuts from Ntigha, minimum significant positive correlation was found in Mg-Na ($r= 0.887$) and Fe-K ($r=0.959$) at 0.05 and 0.01 levels respectively, while maximum significant positive correlation exists in Ni-Ca & Cu-Na ($r= 0.951$) and Zn-Fe ($r= 0.998$) at 0.05 and 0.01 levels respectively. For products from Uturu, Mg-Zn ($r= 0.891$) and Na-Fe ($r= 0.944$) had the minimum significant positive correlation at 0.05 and 0.01 levels respectively, while maximum significant positive correlation was found in Ca-K ($r= 0.963$) and Fe-K ($r= 0.992$) at 0.05 and 0.01 levels respectively. Amongst the metals in samples from Uzuakoli, the minimum positive correlation of Na-Ca ($r = 0.890$) and Mn-Cu ($r= 0.963$) was significant at 0.05 and 0.01 levels respectively, while Mg-Ca & Zn-Fe ($r= 0.958$) and Fe-Ni ($r= 0.992$) showed maximum positive correlations that were significant at 0.05 and 0.01 levels respectively. In Obehie, it was discovered that the minimum and maximum significant positive correlation at 0.05 level exist in Na-Fe ($r= 0.880$) and Mg-Fe ($r= 0.956$) respectively, while the minimum and maximum significant positive correlation at 0.01 level was found in Ca-Mn ($r= 0.958$) and Fe-Mn ($r= 0.995$) respectively.

Table 3. Elements content of cashew nut from areas in Southeastern Nigeria (mg/kg; Mean (n= 5), SD, Range and Median)

Element	Uturu	Uzoakoli	Obehie	Ubakala	Omoba	Ntigha	Combined (n=30)
Ca	420±10	360±40	310±20	370±10	330±20	390±10	360±40
	400–430	310–400	290–330	350–380	300–350	380–410	290–430
	420	360	300	370	330	390	380
Cr	0.06±0.03	0.09±0.03	0.11±0.03	0.043±0.021	ND	ND	0.078±0.036
	<0.001–0.08	<0.001–0.12	<0.001–0.14	<0.001–0.060	–	–	<0.001–0.14
	0.03	0.06	0.09	0.02	–	–	–
Cu	25±1	22±1	23±1	23±2	22±2	23±2	23±2
	23–26	21–24	21–24	21–24	21–25	21–25	21–26
	25	22	23	23	22	22	23
Fe	69±3	62±3	62±2	70±3	75±3	74±3	69±6
	66–72	59–67	60–65	66–74	71–79	70–78	59–79
	70	62	63	69	75	74	70
K	7000±90	6100±260	6200±300	6100±140	5800±230	6100±100	6200±130
	6900–7100	5900–6600	5900–6700	5900–6200	5400–6000	6000–6200	5400–7100
	7000	6000	6000	6000	5900	6100	6100
Mg	2900±140	2700±60	2900±50	2900±40	2900±100	2900±130	2900±110
	2700–3100	2700–2800	2900–3000	2800–2900	2700–3000	2700–3000	2700–3100
	2900	2700	2900	2900	2900	3000	2900
Mn	22±2	21±1	21±1	18±1	20±1	22±1	21±2
	20–24	19–77	20–22	17–19	19–22	20–22	17–24
	22	21	22	18	21	22	21
Na	2500±70	2400± 60	2600±150	2500±70	2500±100	2900±110	2600±180
	2500–2600	2300–2500	2500–2900	2400–2600	2500–2700	2800–3000	2300–3000
	2500	2400	2600	2500	2500	2900	2500
Ni	0.28±0.04	0.22±0.04	0.18±0.04	0.36±0.07	0.27±0.03	0.21±0.03	0.25±0.07
	0.24–0.35	0.17–0.28	0.15–0.24	0.25–0.44	0.24–0.31	0.18–0.25	0.15–0.44
	0.28	0.21	0.18	0.35	0.26	0.21	0.25
Zn	67±3	72±4	61±3	75±4	70±3	77±4	71±6
	62–70	69–77	58–65	69–80	66–75	73–81	58–81
	69	70	60	76	70	78	59

ND : Not detected ; detection limit = 0.001 mg/kg

3.3 Estimation of micro-nutrient intake

The consumption of 35–79 g of roasted cashew nut daily will furnish the body with 217–489 mg of K; 91–205 mg of Na and 13–28 mg of Ca daily. The recommended daily intake for Ca is 800 mg [21], thus daily consumption of cashew nuts supplies the human body with essential Ca at <5% of adequate intake. The amount of Na a consumer derives on eating 35–79 g of cashew nuts is adequate and is in no way likely to pose risk of hypertension. The recommended minimum dietary allowance for Na is 1500 mg/day and maximum of 2400 mg daily [22, 34]. Thus it will take the consumption of about 923 g (26 wraps of ₦50 or 12 wraps of ₦100 worth) of roasted cashew nuts to exceed the maximum limit, which is about 11.6 times the calculated quantity consumed daily. Similarly, consumers should not be concerned over potassium toxicity from consumption of roasted cashew nuts, because the intake value is far below the recommended dietary allowance of 4700 mg/day [21].

The Food and Nutrition Board [35] recommends dietary Mg allowance of 300 mg/day for women and 350 mg/day for men. The intake of Mg on consumption of 35–79 g cashew nuts is between 102 and 229 mg daily, thus it will take the consumption of about 103 to 120 g of cashew nuts daily to exceed these limits.

Daily reference values of 2 and 18 mg for Cu and Fe respectively were set by FDA [20]. The daily consumption of 35–79 g of cashew nuts will supply the body with 0.8–1.8 mg and 2.4–5.5 mg of Cu and Fe daily respectively. For Cu, this will amount to 40–90% of the daily reference value, and for Fe it will amount to 13–31% of the daily reference value. Thus cashew nuts are good sources of Cu and Fe; it will only take the daily consumption of 87 g and 261 g of cashew nuts to exceed the daily reference values of Cu and Fe respectively. For Zn, this consumption will provide the body with 2.5–5.6 mg of element daily, while the FDA recommends a daily reference value of 15 mg for Zn. The levels of Zn derived from the consumption of cashew nuts per day are about 17-37% of the reference value. Zn exerts anti-diarrhea activity and regulates fertility; hence the consumption of cashew nuts is recommended for both men and women without any attendant health risk.

The Institute of Medicine [23] recommends an RDI of 0.5 mg for Ni; while Food and Drug Administration [20] recommends 2 mg as a RDI for Mn. The consumption of 35–79 g of cashew nuts will supply 0.009–0.02 mg of Ni and 0.7–1.7 mg of Mn. For Ni, this will amount to 1.8–4% of the RDI, and for Mn, it will amount to 35–85% of the RDI. Studies by Nascimento et al. [17] showed that it is possible to assume that 75 of Cu and 70% of Fe present in cashew nut could be bioavailable. This buttresses the value of cashew nuts as a good source of these elements in human diet.

Earlier, studies have shown that the cashew nut contains 47% fat, 21% protein and 22% carbohydrate as well as vitamins, especially thiamine [5, 36]. Similarly, the protein content of cashew nut has been show to be complete, having all the essential amino acids. Cashew nuts also provide more energy compared to other foods. For instance, a kilogramme of cashew nut yields about 6000 calories compared to 3600 calories from cereals, 1800 calories from meat and 650 calories from fresh citrus fruit [37]. Similarly, Nayar [1] observed that cashew nuts have only 1% of soluble sugar; consequently, the consumer of cashew is privileged to get a sweet taste without having to worry about excess calorie intake from sugary substances.

3.4 Principal component analysis (PCA)

PCA was employed to reveal possible spatial variations in the metal constituents of cashew nut according to the study areas (Fig. 1). The analysis was based on correlation matrix; the accepted significance level of <0.05 was selected and the probability associated with the Bartlett's test is <0.001. The Kaiser Criterion was employed in choosing the number of components, and only factors with eigenvalues greater than 1 were retained [19]. In addition, loadings <0.5 are considered poor while loadings >0.9 are typically regarded as excellent.

Table 4 shows the factor loadings, number of significant factors, and total variance (%) that were explained by using Varimax with Kaiser normalized rotation method. PCA data revealed that a 2-component solution (varifactors) would be sufficient to explain 75.81% of the total variance (Table 4 and Fig. 1). The factor loadings (Table 4) demonstrated that the first varifactor (V1) explained 43.43% of the total variance and loaded primarily by positively correlated Ca, Cu, K, Mg, Mn and Ni (range of loadings: 0.714–0.943). The second varifactor (V2) explained 32.38% of the overall variance and was loaded heavily on the positively correlated variables describing Fe, Na and Zn (loadings ranging from 0.801 - 0.871). The interrelationships among the metals in the two varifactor spaces are shown as PCA plots (Fig. 1). Careful observation of Figure 1 shows that elements clustered in groups. For example, the cluster Fe-Na-Zn is linked with the first varifactor, while Ca-Ni-Mg-Mn is linked with the second varifactor. Metals in each of the two varifactors showed very strong positive correlation suggesting the metals could be of natural sources only.

Table 4. Factors loading after Varimax normalized rotation

Element	V1	V2
Ca	**0.743**	0.426
Cu	**0.882**	0.270
Fe	0.230	**0.871**
K	**0.943**	-0.054
Mg	**0.623**	0.473
Mn	**0.801**	0.421
Na	0.222	**0.801**
Ni	**0.714**	0.390
Zn	0.221	**0.840**
Variability (%)	43.431	32.383
Cumulative (%)	43.431	75.814

Note: Values in bold correspond for each variable to the factor for which the squared cosine is the largest

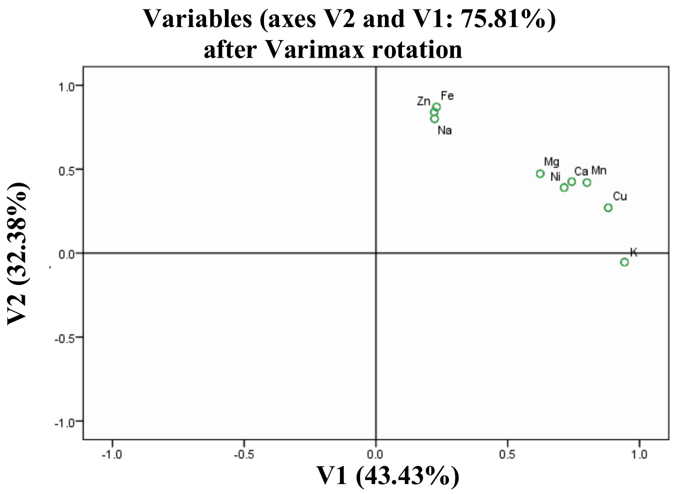

Figure 1. Plots of loadings (Varimax rotation) based on the concentration of elements in cashew nuts in space of first and second varifactors

IV. Conclusion

The results of this study provide detailed information on some micro- and macro-element contents of roasted cashew nuts on sale in southeastern Nigeria and the benefits of regular consumption of roasted cashew nuts, and contribute to the existing data. The results shows roasted cashew nut from southeastern Nigeria to be very rich in K, Mg, Ca, and Na ranging from 5400–7100, 2700–3100, 290–430 and 2300–3000 mg/kg respectively, with undetectable levels of Cd and Pb. Evaluations of metals intake from the consumption of cashew nuts have shown that occasional or relatively frequent eating of cashew nuts does not pose any toxicological health concern, rather it will constitute a good source of nutrients including Fe, Cu and Zn. This study identified slight variations in the metals content of roasted cashew nuts from different towns in southeastern Nigeria. This could result from the variation in the mineral compositions of soils in which the cashew trees grew or from variations in the cashew nuts preparation and roasting methods. The result of PCA analysis showed interrelationships among the metals and suggest that metals contained in cashew nuts could be of natural sources.

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Table 1S. Correlation matrix of elements in samples from Ubakala and Omoba

		Ca	Na	K	Mg	Ni	Cu	Fe	Mn	Zn		
Ubakala	Ca	1	0.861	0.852	0.923*	0.938*	0.144	-0.329	-0.003	0.322	Ca	Omoba
	Na	0.708	1	0.755	0.986**	0.946*	0.061	-0.172	-0.415	0.149	Na	
	K	0.982**	0.618	1	0.846	0.780	-0.071	-0.369	-0.197	0.599	K	
	Mg	0.842	0.973**	0.761	1	0.964**	0.048	-0.245	-0.339	0.251	Mg	
	Ni	0.921*	0.895*	0.894*	0.949*	1	-0.067	-0.425	-0.308	0.061	Ni	
	Cu	0.976**	0.656	0.996**	0.783	0.920*	1	0.814	0.663	0.438	Cu	
	Fe	0.941*	0.863	0.870	0.939*	0.938*	0.878	1	0.326	0.301	Fe	
	Mn	0.960**	0.875	0.916*	0.953*	0.985**	0.930*	0.980**	1	0.329	Mn	
	Zn	0.881*	0.956*	0.820	0.992**	0.981**	0.845	0.951*	0.977**	1	Zn	

**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).

Table 2S. Correlation matrix of elements in samples from Ntigha and Uturu

		Ca	Na	K	Mg	Ni	Cu	Fe	Mn	Zn		
Ntigha	Ca	1	0.907*	0.963*	0.912*	0.781	0.977**	0.987**	0.930*	0.987**	Ca	Uturu
	Na	0.968**	1	0.952*	0.983**	0.857	0.945*	0.944**	0.988**	0.894*	Na	
	K	0.919*	0.949*	1	0.979**	0.875	0.960**	0.992**	0.937*	0.930*	K	
	Mg	0.800	0.887*	0.845	1	0.921*	0.948*	0.958*	0.960**	0.891*	Mg	
	Ni	0.951*	0.943*	0.986**	0.831	1	0.868	0.828	0.837	0.790	Ni	
	Cu	0.976**	0.951*	0.963**	0.835	0.992**	1	0.972**	0.969**	0.987**	Cu	
	Fe	0.941*	0.995**	0.959**	0.906*	0.939*	0.936*	1	0.944*	0.960**	Fe	
	Mn	0.797	0.894*	0.823	0.994**	0.803	0.810	0.912*	1	0.936*	Mn	
	Zn	0.933*	0.989**	0.972**	0.898*	0.949*	0.939*	0.998**	0.899*	1	Zn	

**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).

Table 3S. Correlation matrix of elements in samples from Uzoakoli and Obehie

		Ca	Na	K	Mg	Ni	Cu	Fe	Mn	Zn		
Uzoakoli	Ca	1	0.973**	0.987**	0.985**	0.992**	0.992**	0.962**	0.958**	0.994**	Ca	**Obehie**
	Na	0.890*	1	0.989**	0.930*	0.970**	0.811	0.888*	0.880*	0.952*	Na	
	K	0.828	0.860	1	0.955*	0.978**	0.860	0.913*	0.901*	0.982**	K	
	Mg	0.958*	0.926*	0.804	1	0.959**	0.942*	0.956*	0.956**	0.984**	Mg	
	Ni	0.937*	0.933*	0.955*	0.944*	1	0.920*	0.971**	0.960**	0.982**	Ni	
	Cu	0.964**	0.938*	0.890*	0.987**	0.985**	1	0.982**	0.980**	0.936*	Cu	
	Fe	0.894*	0.899*	0.981**	0.898*	0.992**	0.957*	1	0.995**	0.959**	Fe	
	Mn	0.987**	0.849	0.867	0.940*	0.952*	0.963**	0.925*	1	0.950*	Mn	
	Zn	0.913*	0.982**	0.938*	0.918*	0.974**	0.956*	0.958*	0.899*	1	Zn	

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).