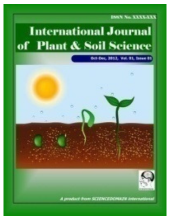

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Mineral Contents of *Ukwa*, African Breadfruit (*Treculia africana*), from South-Eastern Nigeria: Effect of Methods of Preparation

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Authors' contributions

This work was carried out in collaboration between all authors. Author ICN designed the study, wrote the protocol and the first draft of the manuscript. Authors EU and ICN managed the literature searches, while authors FO, MO, PA and IPE managed the experimental process and performed the spectroscopic analysis. Author UE performed the statistical analysis and revised the first draft of the manuscript. All authors read and approved the final manuscript.

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ABSTRACT

Aims: Major and trace elements (Ca, Cd, Co, Cr, Cu, Fe, K, Mg, Mn, Na, Ni Pb, and Zn) were determined in 32 samples of *ukwa, Treculia africana* (African breadfruit).
Study Design: The study was conducted on *ukwa* samples collected from 8 towns in Abia State, South-eastern Nigeria, between January and February, 2013.
Methodology: Analysis of *ukwa* samples prepared using different methods (raw, dried, fried and boiled) was conducted using atomic absorption spectrophotometer after acid digestion.
Results: The major elements contents (mgkg^{-1}) of *ukwa*, irrespective of method of preparation, ranged from 3600-5500 for Ca, 1200-2100 for K, 660-1100 for Na and from 690-980 for Mg. The

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contents (mgkg^{-1}) of Cu ranged from 10-28, 55-85 for Fe, 14-40 for Mn, 25-45 for Zn; Pb and Cd were <0.006; while Cr and Ni were <0.2 and <0.04 respectively. The methods of preparation did not significantly (*P*=.05) influence the levels of metals in breadfruits. Principal Component Analysis (PCA) showed that the elements tend to cluster in groups with Ca-Cu-Mg-Mn linked with the first varifactor, while pairs of Zn-Fe and Na-Fe were linked with the second and third varifactors respectively.

Conclusion: The results of this study have shown that *ukwa* is a rich dietary source of Zn, Mn, Fe, Cu, Ca, Co, Cr, Mg, K, and Na without posing toxicological health risk due to Pb and Cd to consumers.

Keywords: Breadfruit; micronutrient; heavy metals; Nigeria; ukwa.

1. INTRODUCTION

Treculia africana (African breadfruit) is a plant member of the *Moraceae* family and is a native of the East Indies [1]. It is a large tree which grows in wet and forest areas of tropical Africa; it is generally cultivated in the tropics and its tree could grow up to be 40-50 ft high [2]. The seeds from the fruit are edible and are of high nutritional values [3]. It has been estimated that the fruit may contain as much as 1,500 seeds [4] whose length is about 8.5mm [5]. African breadfruit is popular in Nigeria and other countries, such as Senegal, Sudan and Angola; the tree grows well in the riverine forest of tropical Africa, Madagascar, Uganda and Tanzania [6].

The seeds are used in the preparation of delicacies in most communities in Nigeria. It is highly valued and enjoyed mostly by the *Igbos* and *Yorubas* of the south-eastern and south-western Nigeria, where it is referred to as "*ukwa"* and "*afon"* in local parlance respectively. African breadfruit is prepared and consumed in many forms. Fasasi and co-workers described the various methods of processing and consuming the seeds of African Breadfruit as follows: "… (the) seeds are usually roasted or blanched then cooked, mashed and served with yam or made into ‘‘*ukwa*’’ porridge by the *Igbo's* of Nigeria [2]. They may also be salted, roasted, dehulled and eaten as snack or ground and used as thickeners in local soups"[2].

African breadfruit seeds have been reported to be rich in proteins, lipids and minerals [7,8]. The seed is reported by Ajiwe et al. to contain about 20.83% semi-drying oil [1]. Edet and co-workers reported 13·4% protein, 18·9% lipid, 58·1% carbohydrate, 1·4% crude fibre, 2·1% ash, 7·8% moisture content; as well as vitamins B_1, 5mgkg^{-1}; B_2, 3mgkg^{-1}; C, 451mgkg^{-1} and β-carotene, 60mgkg^{-1} [9]. Vast literatures are also available on the studies of African breadfruit in Nigeria; ranging from cultivation [10], storage methods and diseases [11,12], proximate and nutrient composition of the prepared meals [7,9,13,14] to functional and storage properties of flours from raw and heat processed African breadfruit [15]. Literature observed that roasting of the raw unprocessed seeds of *T. africana* did not bring about any significant difference (P=·05) in ether extract, crude protein, dietary fibre, ash or carbohydrate contents of the raw and roasted seeds [14]. However, moisture content (P=·01) showed a significant decrease (16·1%) while the mineral analysis showed increases of potassium (39·2%) and calcium (28·2%) [14]. Other studies have investigated the use of *ukwa* in bread production [15] and in food formulations [16].

Human exposure to toxic elements occurs through a variety of routes, including the inhalation of air pollutants and the consumption of contaminated foods and water; hence it is important to monitor foods for contamination. For non-occupationally exposed individuals, the most likely source of trace elements intake is the diet. Local delicacies such as *ukwa* which may not have been extensively investigated for micronutrients and toxic metal contents, could serve as routes for intake of beneficial elements or as sources of risk exposure to toxic metals. Information on food and feedstuff contamination with heavy metals as well as consumers' dietary intake is very important for assessing health risks to humans. Research and surveillance of toxic metals in foods and foodstuff is advisable because of their known toxic effects [17]. Exposure to some toxic metals can have both acute and chronic health risks.

Several studies have focused on the chemical properties and nutrient composition of *ukwa* [2,7,8,18-22]. However, there is dearth of information on the major and trace metals composition of this well consumed food product. The aim of the present investigation was to quantify the levels of 14 major and trace elements (Ba, Ca, Cd, Cr, Cu, Fe, K, Mg, Mn, Na, Ni, Pb, Zn and V) in African breadfruit seed (*Treculia africana*). Based on the results obtained, the potential health risk of dietary intake of toxic metals such as Pb and Cd as well as the nutritional benefits of micronutrient intakes from the consumption of *ukwa* will be discussed. Similarly, the effect of method of preparation on the trace metals contents was also investigated.

2. MATERIALS AND METHODS

2.1 Sampling

Ukwa (African breadfruit) samples from eight towns (Asa-Ngwa, Isiala-Ngwa, Ntigha, Obiehi, Omoba, Ubakala, Umudike and Isuikwuato) in Abia State, Southeastern Nigeria were sampled and studied between January and February, 2013. For each of the towns, fresh (raw, uncooked) *ukwa* seeds were purchased from three sellers from two (2) separate rural markets (total of six samples per town) and then made into one composite. A total of eight composite samples were obtained (one per town) for subsequent processing and use in this study.

2.2 Sample Pre-Treatment

The composite sample from each town was treated in three different ways - dried, fried, boiled - and thereafter analyzed alongside with the raw sample (which was designated as 'unprocessed' – analyzed 'as is' without pretreatment). The processed or 'treated' samples (dried, fried and boiled) were prepared as described below:

2.2.1 Unprocessed samples

Analyzed 'as is' (with the husk) without prior treatment

2.2.2 Dried Samples

The raw seed samples were blanched in a 250mL conical flask at 100℃ for 10 min, drained through a plastic sieve, and the husks peeled and separated from the seeds. The dehulled seeds were then sun-dried, and thereafter packed in new sealable polyethylene bags ready for laboratory analysis.

2.2.3 Fried samples

The raw samples were blanched in a 250mL conical flask at 100℃ for 10min, drained through a plastic sieve, and thereafter dehulled. The samples were fried by heating in an oven at a temperature of 105℃ until it turned brown and was ready for eating as processed by local vendors. Samples were packed in new sealable polyethylene bags ready for laboratory analysis.

2.2.4 Boiled samples

The raw samples were initially blanched as indicated above, drained through a plastic sieve, and then dehulled. The dehulled samples were then boiled until they were soft and ready for eating. The samples were sifted and allowed to dry at room temperature. No other ingredients were added. Samples were allowed to cool and thereafter packed in new sealable polyethylene bags ready for laboratory analysis.

2.3 Sample Analysis

All samples were analyzed as prepared above without any further pre-treatment. Samples were crushed in porcelain mortar, homogenized and then dried to constant weight. 1 g was ashed in a muffle furnace at a temperature of 450ºC for 5h and the ash transferred quantitatively into a 250mL conical flask and thereafter digested with 10mL of the digestion acid mixture (ratio 1:2:2 of perchloric, nitric and sulphuric acids) with heating on a hot plate in a fume hood until evolution of white fumes. The digest was allowed to cool and 20mL of distilled water was added to bring the metals into solution; and then filtered using ashless Whatman filter paper into a 100mL calibrated volumetric flask and made up to mark with distilled water. The digests were subsequently analyzed for Ba, Ca, Cd, Cr, Cu, Fe, K, Mg, Mn, Na, Ni, Pb, V and Zn using Phoenix 986 (Biotech Engineering Management Co. Ltd. UK) flame atomic absorption spectrophotometer.

The elements, Ba and V were found to be below the detection limits of the instrument; hence the results for these elements were not presented.

2.4 Quality Assurance

Appropriate quality assurance procedures and precautions were carried out to ensure the authenticity of the results. Samples were generally handled carefully to avoid contamination. All chemicals used were of analytical grade: $HClO_4$ (70%, Sigma-Aldrich, USA); H_2SO_4 (98%, BDH Laboratory Supplies, Poole, England); HNO_3 (69%, BDH Laboratory Supplies, Poole, England). 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 24h. 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 (Accu Standards, New Haven Connecticut, USA). Also, a recovery test of the total analytical procedure was carried out for some of the metals in selected samples by spiking analyzed samples with aliquots of metal standards and then re-analyzing the samples. Detection limit was defined as the concentration corresponding to three times the standard deviation of seven blanks. Recoveries for the certified reference CRM varied from 95 – 107%, and for the spiking study, from 99–109%.

2.5 Assessment of Metals Intake

Our survey showed that a regular *ukwa* meal is about 300g/person per meal. This value (300 g/person per meal) was used in estimating elements intakes by consumers. Daily intake of essential and toxic elements (mg/day) from breadfruit was estimated using the mean result of the metals ($mgkg^{-1}$) and the quantity consumed per day. The daily intake of metals from breadfruit consumption was compared with the Recommended Daily Intake (RDI) values.

2.6 Statistical Analysis

Statistical analyses of data were carried out using SPSS 16.0 for windows (SPSS Inc., Polar Engineering and Consulting, 2007) and Origin® 6.0 statistical package programs. One-way ANOVA was employed to check if there were significant differences between the mean metal concentrations in breadfruit samples with respect to method of preparation as well as sampling areas. The mean differences were considered significant at P=.05. The use of Principal Component Analysis (PCA) in this study was to visually explore the principal attributes of the analytical data and distribution of elements concentrations in breadfruit, which will be difficult to recognize with tables alone.

3. RESULTS AND DISCUSSION

3.1 Elemental Concentrations of Breadfruit

Among the macro elements, Ca showed the highest concentrations ranging from ($mgkg^{-1}$ dry weight) 3600–4600 in boiled, 3600–5500 in fried, 3700–5400 in dried, to 4000–4600 in unprocessed samples (Table 1). Potassium had the highest mean concentration in unprocessed breadfruit ($1600\pm150 mgkg^{-1}$) while the lowest mean was observed in boiled samples ($1400\pm190 mgkg^{-1}$). Na and Mg had similar results with the highest mean concentrations found in unprocessed breadfruit and the least in the boiled specimens. Median concentrations of Na in boiled, fried, dried and unprocessed samples were 760, 810, 810 and $820 mgkg^{-1}$ respectively, while Mg had median concentrations of 700, 710, 710 and $750 mgkg^{-1}$ for boiled, fried, dried and unprocessed samples respectively. From the foregoing, it appears that the concentrations of macro elements in the processed samples are similar.

Fe concentration ranged from $55–75 mgkg^{-1}$ in dried, $57–77 mgkg^{-1}$ in fried, $55–80 mgkg^{-1}$ in boiled and $63–85 mgkg^{-1}$ in unprocessed breadfruit. The concentration of other elements in the samples irrespective of sample condition (processed or unprocessed) is in the order: Zn>Mn>Cu>Cr>Ni (Table 1). Mean Mn concentrations were 22±8 for dried, 23±7 for fried, 23±7 for boiled and 26±9 $mgkg^{-1}$ for unprocessed samples while the corresponding values for Cu were 15±6, 15±4, 14±4 and 16 ± 3 $mgkg^{-1}$ for dried, fried, boiled and unprocessed samples respectively.

In processed samples, both Cr and Ni showed concentrations <0.1 $mgkg^{-1}$ (median values ranged from 0.01–0.02 for Ni and 0.07–0.09 for Cr). Similarly, Pb and Cd were generally low and not detected in some samples with a maximum concentration of 0.002 $mgkg^{-1}$ in dried, fried and boiled samples respectively. For unprocessed samples, the Cd and Pb concentrations ranged from 0.001–0.004 and $0.001–0.005 mgkg^{-1}$ respectively. However, there were no observed significant differences in the mean concentrations of Cd and Pb in the differently prepared and unprocessed samples. Concentrations (≤0.002 $mgkg^{-1}$) of Cd and Pb in *ukwa* samples were very low compared to 0.05 and $0.1 mgkg^{-1}$ respectively, being European standard limit given for fruits, excluding berries and small fruits [23]. In most food products, the nickel content is less than 0.5 $mgkg^{-1}$ fresh weights. Cacao products and nuts may, however, contain as much as 10 and 3$mgkg^{-1}$, respectively [24]. The Ni concentration of the studied breadfruit samples were however lower in comparison.

Earlier, Edet and co-workers had obtained the following concentrations of mineral elements in African breadfruit: Na, 70$mgkg^{-1}$; Mg, 1840 $mgkg^{-1}$; Ca, 175$mgkg^{-1}$; K, 5850$mgkg^{-1}$; P, 3820$mgkg^{-1}$; Cu, 39$mgkg^{-1}$; Fe, 16$mgkg^{-1}$; Cr, 2 $mgkg^{-1}$ and Zn, 75$mgkg^{-1}$ [9]. Our results for Mg, Cu, Cr, K and Zn were lower than the above corresponding values, whereas the opposite was the case for the other metals investigated.

3.2 Elemental Variations of Processed and Unprocessed Samples

The result of one-way ANOVA (P=.05) showed that the method of preparation did not significantly influence the metal concentrations of breadfruit. However the sampling location significantly influenced the metal contents of both processed and unprocessed breadfruit samples.

This variation could be as a result of differences in the species investigated (if any), age of plant, mineral contents of the soils on which the plants grew as well as on other anthropogenic sources. Fig. 1 shows the percentage of elements in each form of prepared samples compared to the unprocessed samples. It could be seen that none of the various forms of prepared samples contained as much (i.e. 100%) elements as the unprocessed samples. This invariably shows that the preparation methods may have resulted in the loss of the elements determined or that the husk contained traces of these elements since it was not removed in the unprocessed samples.

The percentages of Ca, Na, K and Mg in boiled, fried and dried samples were generally >90% (Fig. 1), of the unprocessed samples; the Cu, Fe, Mn and Zn percentages ranged between 87 and 91%, while Ni has percentages below 65% and Cr percentage was between 57 and 59%.

3.3 Dietary Intake of Beneficial Minerals and Potentially Toxic Metals

Intake of elements from food consumption is dependent on the element concentrations in food and the amount of food consumed. Considering the ranges of essential elements in the samples studied, breadfruit would serve as a vital source of these elements to humans. Eating 300g of fried breadfruit will supply the body with 1081–1660 mg of Ca, 204–274mg of Na, 363–575mg of K and 207–254mg of Mg. In the same way, 300 g of boiled breadfruit will provide 1067–1374 mg of Ca, 195–270mg of Na, 347–524mg of K and 206–262mg of Mg. Within the study locations, people consume more of fried breadfruits than the boiled because of the ease of preparation and availability (it is readily hawked along road sides, markets, public places and it keeps longer than the cooked).

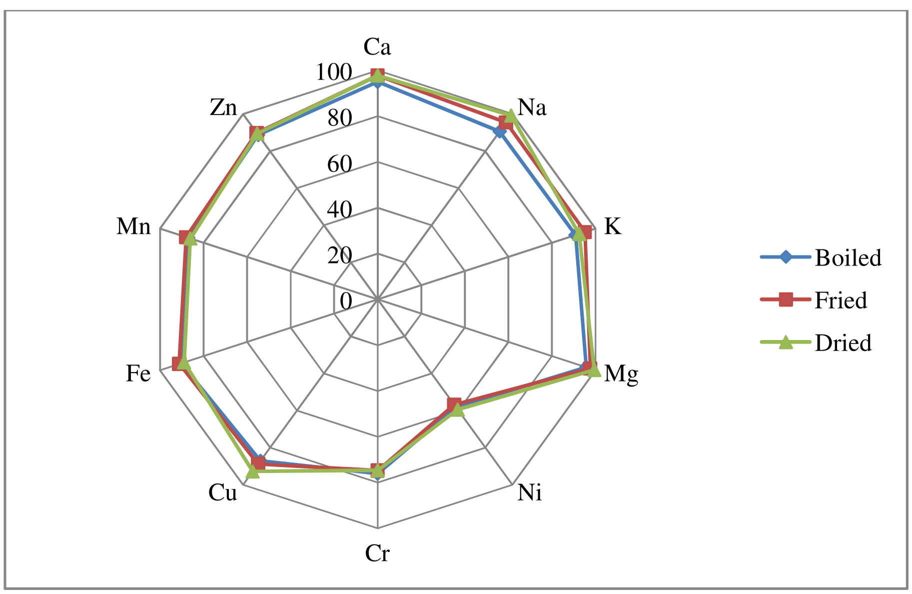


Fig. 1. Percentage of metals in processed samples compared to the unprocessed samples

Table 1. Elemental contents (mgkg^{-1}) of breadfruit in processed and unprocessed samples irrespective of sampling sites

	Processed samples									Unprocessed samples		
	Dried (n = 8)			Fried (n = 8)			Boiled (n = 8)			With Husk (n = 8)		
	Mean ± SD	**Median**	**Range**	**Mean ± SD**	**Median**	**Range**	**Mean ± SD**	**Median**	**Range**	**Mean ± SD**	**Median**	**Range**
Ca	4200±540	4000	3900-5400	4200±580	4000	3600-5500	4100±300	4000	3600-4600	4300±250	4200	4000-4600
Cd	0.001±0.001	-	ND-0.002	0.001±0.000	-	ND-0.001	0.001±0.001	-	ND-0.002	0.002±0.001	0.002	0.001-0.004
Cr	0.068±0.015	0.065	0.050-0.090	0.068±0.007	0.070	0.060-0.080	0.069±0.014	0.065	0.050-0.090	0.090±0.015	0.090	0.060-0.110
Cu	15±6	13	11-28	15±4	13	11-23	14±4	13	10-22	16±3	16	13-22
Fe	62±7	59	55-75	64±7	61	57-77	63±8	60	55-80	70±8	67	63-85
K	1500±320	1400	1200-2100	1500±210	1500	1200-1900	1400±190	1400	1200-1700	1600±15	1600	1300-1800
Mg	760±100	710	710-980	740±70	710	690-850	730±60	700	690-870	760±60	750	700-860
Mn	22±8	19	14-39	23±7	20	15-36	23±7	20	15-37	26±9	23	15-40
Na	840±50	810	660-1100	810±80	810	680-910	770±90	760	650-850	850±90	820	690-1000
Ni	0.012±0.005	0.010	0.010-0.020	0.011±0.004	0.010	0.010-0.020	0.013±0.005	0.010	0.010-0.020	0.020±0.008	0.020	0.010-0.030
Pb	0.001±0.001	-	ND-0.001	0.001±0.001	-	ND-0.002	0.002±0.001	-	ND-0.002	0.003±0.001	0.003	0.001-0.005
Zn	31±6	28	25-41	31±5	28	26-39	31±6	29	25-44	35±6	33	28-45

ND means Not Detected, Instrument detection limit is 0.00mgkg^{-1}

The recommended minimum dietary allowance for Na is 1500 mg/day and maximum of 2400mg daily [25,26]. Thus, consuming fried breadfruit does not elevate the risk of hypertension and cardiovascular disease (supposing no other Na intake) and one will need to consume as much as 3.5kg breadfruit to exceed the maximum allowable limit. Consumption of 300g of fried breadfruit will provide the body with enough calcium in the range of 1080-1660mg. The recommended nutritional allowance for Ca is between 800 and 1200 mg daily [27,28]. Experts believe that elderly persons should take as much as 1500mg of Ca to help prevent osteoporosis [29].

The K intake on consumption of 300 g of breadfruit is between 347 and 644mg per day irrespective of the method of preparation. The reference daily intake of K is 4700mg/day [28]. Thus, consuming 300g of breadfruit in a meal daily will provide the appropriate nutrient without any attendant health risks.

Mg is needed by the body to activate numerous enzymes that control the metabolism of carbohydrates, fats and electrolyte [30]. African breadfruit, irrespective of the method of preparation will serve as a good source of this essential element. Consuming 300 g of breadfruit will result in the intake of 207–254mg of magnesium from fried and 206–262mg from boiled *ukwa*. The Food and Nutrition Board recommends a dietary Mg allowance of 300 mg per day for women and 350mg per for men [29]. Thus, it will take the consumption of between 440 and 510 g of breadfruit to exceed these limits depending on the method of preparation.

Elements such as zinc, iron, copper and manganese are essential elements since they play important roles in biological systems [31]. Copper is essential for good health but very high intake can cause adverse health problems such as liver and kidney damage [32]. Copper deficiency leads to hypochromic anemia, leucopenia and osteoporosis in children [33]. Breadfruit would serve as a good source of Cu and Zn, though the consumption should be regulated in order not to exceed the recommended limits for these elements. Tolerable intake of Zn and Cu in adults is estimated at 10 mg and 1.5–4 mg per day respectively [34]. A 300g of fried breadfruit will provide the body with 3.2–7.0mg of Cu and 7.7–11.6mg of Zn daily, while the same quantity of boiled breadfruits will provide 3.1–6.3mg of Cu and 7.6–13.2mg of Zn daily. For Zn, these intakes would be 77–116% and 76–132% of the tolerable intake limits for fried and boiled *ukwa* respectively. Zinc is known to be involved in most metabolic pathways in humans and its deficiency can lead to loss of appetite, growth retardation, skin changes and immunological abnormalities [35]. Thus, consuming breadfruit (assuming no other Zn intake) provides the body with adequate Zn. For Cu, the intakes would exceed the lower recommended intake limit of 1.5mg per day (214–467% of the lower limit) and would amount to 80 – 175% of the upper limit of 4 mg per day,

Adequate intake of Fe is very important for decreasing the incidence of anaemia [36]. According to literature, the recommended intake for adults is 18mg [37]. Hence, the consumption of 300 g of fried or boiled breadfruit will provide the body with 17.1–23.1mg or 16.6–24.1mg/day respectively. Thus, such quantity of breadfruit is likely to curb the menace of anaemia. Also, the range of Mn intake upon the consumption of 300 g of breadfruit is between 4.5 and 10.7 mg in fried and 4.4–11.0mg in boiled daily. Recommended intake of 2.5–5 mg per day has been given by US National Academy of Science [38], thus, consumption should be regulated in order not to exceed the limits.

The adequate intake of Cr is estimated at 25µg per day for adults and between 0.1 and 1.0µg for children and adolescents [39]. Thus consuming 300g of fried breadfruit will supply the body with 0.018 – 0.024mg (18–24µg) which is 72–96% of 25 µg per day recommended for adults, while consumption of the same quantity of boiled breadfruits will provide 0.015 – 0.027mg (15 – 27µg) daily.

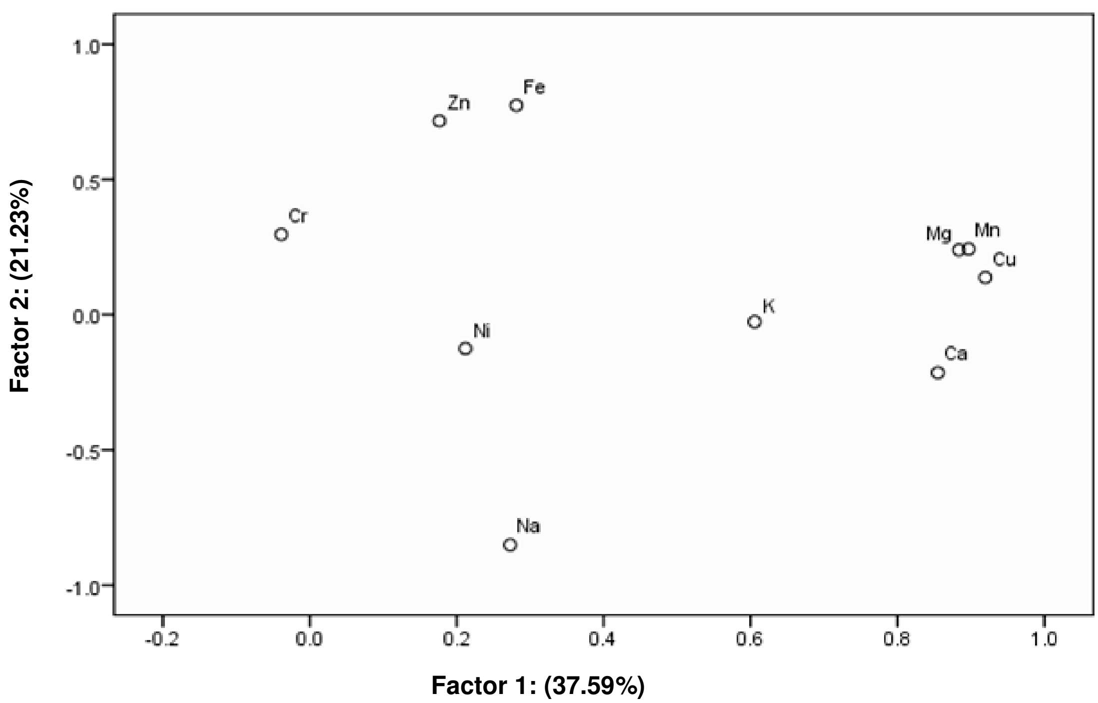
Trace amounts of Ni may be beneficial as an activator of some enzyme systems, but its toxicity at higher levels is more prominent [35]. The results of this study showed that the consumption of 300g of fried and boiled breadfruit would amount to a Ni intake of between 0.003 and 0.006 mg per day.

Trace amounts of Cd and Pb were found in the fried and boiled samples and the consumption of 300g will result in the intake 0.3µg and 0.6µg respectively. The acceptable daily intake of Pb for adults is between 0.21 and 0.25mg per day, and between 1.5 and 1.75mg per week [40], while that of Cd is 0.07mg per day [41]. Thus, *ukwa* consumption does not pose any toxic consequence resulting from Pb or Cd, supposing there is no other Cd or Pb intake.

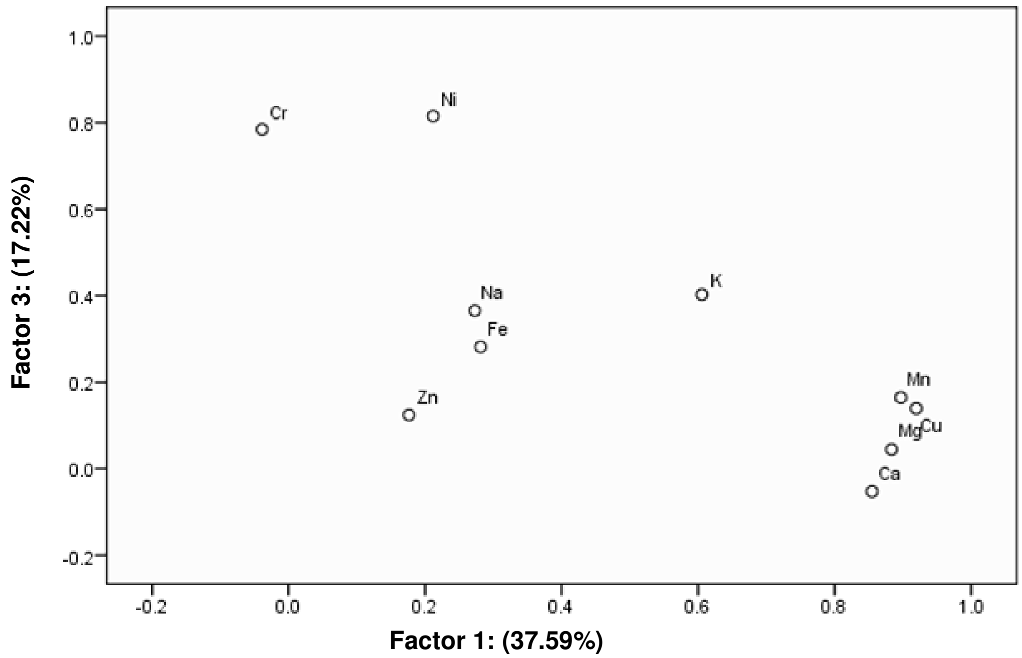
3.4 Principal Component Analysis (PCA)

PCA was used to check for potential relationships between metals in both processed and unprocessed breadfruit samples collected from the eight sites. The analysis was based on correlation matrix and an accepted significance level of .05 was selected. The probability associated with the Bartlett's test is <0.001, which satisfied the requirement that it should be less than the level of significance [42]. The Kaiser Criterion was used in choosing the number of components, and only factors with eigenvalues greater than 1 were retained [43]. Also, loadings greater than 0.9 were considered excellent but those less than 0.5 were unacceptable.

Total variance (%), factor loadings and number of significant factors that were explained by using Varimax with Kaiser normalized rotation method are presented in Table 2. This rotation method was helpful in revealing the interaction of the various elements studied. PCA data indicated that a 3-component solution (varifactors) would suffice to explain 76.041% of the total variance (Fig. 2(a-b) and Table 2). The factor loadings (Table 2) shows that the first varifactor (factor 1) explained 37.59% of the total variance and loaded heavily on the positively corrected variables, describing Ca, K, Mg, Cu and Zn (range of loadings: 0.606-0.919). The second varifactor (factor 2) was loaded primarily with positively correlated Fe and Zn (loadings were in the range of 0.716-0.774) and negatively correlated Na, and accounted for 21.23% of the total variance. The third varifactor (factor 3) was loaded primarily by positively correlated Ni and Cr, which have medium loadings of 0.815 and 0.785 respectively. It was observed that all elements in the varifactors except Na showed strong positive correlation indicating that they must have been from the same source. The interrelationships among the elements in the varifactors space were shown as PCA plots (Fig. 2(a-b). The plots indicated that the elements tend to cluster in groups of two or more. For example, elements Ca-Cu-Mg-Mn were linked with the first varifactor, while the pairs of Zn-Fe and Na-Fe were linked with the second and third varifactors respectively (Fig. 2(a-b)).



a) Variables (axes Factor 2 and Factor 1: 58.82%) after varimax rotation



b) Variables (axes Factor 3 and Factor 1: 54.81%) after varimax rotation

Fig. 2. Plots of loadings (Varimax rotation) based on the concentration of elements in breadfruit in space of first, second and third varifactors

Table 2. Factors loading after varimax normalized rotation

Element	Factor 1	Factor 2	Factor 3
Ca	0.855	-0.215	-0.053
Cr	-0.039	0.297	0.785
Cu	0.919	0.137	0.14
Fe	0.281	0.774	0.282
K	0.606	-0.026	0.403
Mg	0.883	0.239	0.045
Mn	0.897	0.242	0.165
Na	0.273	-0.852	0.365
Ni	0.212	-0.125	0.815
Zn	0.176	0.716	0.124
Variability (%)	37.59	21.227	17.224
Cumulative (%)	37.59	58.817	76.041

4. CONCLUSION

The results of this study have shown the macro and micro nutrients benefits of the consumption of *ukwa* irrespective of the method of preparation. The method of preparation did not significantly influence the metal contents of *ukwa*; rather, sampling area significantly influenced the metal contents of the samples. Considering the RDI limits for the metals investigated, the occasional or regular consumption of *ukwa* is considered safe as the intakes of beneficial metals did not exceed the established limits while the contents of toxic metals, Pb, Cd and Ni were very low. The results of this study provide detailed information on the micronutrient benefits of consuming *ukwa* (*Treculia africana*), prepared for consumption using different methods. This study shows that there is no toxicological health risk from the intake of toxic elements such as Pb, Cd and Ni from the consumption *ukwa*. The information from this study however showed that *ukwa* would serve as a dietary source of Zn, Mn, Fe, Cu, Ca, Co, Cr, K, and Na.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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