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Calcium, zinc and phytate interrelationships in some foods of major consumption in Nigeria

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Abstract

The calcium (Ca), zinc (Zn) and phytate (Phy) contents of 35 Nigerian foods were determined. Levels (mg/100 g) of Ca were 29–45 (legumes), 17–49 (cereals), 17–187 (spices) and 38–155 (tuber/roots) while the Zn levels were 0.55–2.00 (legumes), 0.67–1.84 (cereals), 0.34–4.92 (spices) and 1.35–7.07 (tubers/roots). Phytate levels were 14–344 (legumes), 112–287 (cereals), 35–184 (spices) and 0.0–1070 (tubers/roots). It was found that fermentation reduced Phy levels in *Parkia filicoidea*, *Sorghum bicolor* and *Manihot esculenta* while Phy level was increased in fermented *Zea mays*. The Phy:Zn molar ratios calculated for many legumes, cereals, tubers/roots and one spice analysed were greater than 20:1. Corresponding Ca:Phy molar ratios were generally low in legumes (except for *Sphenostylis stenocarpa*, 54:1), cereals and tubers/roots but generally high in spices (except *Irvingia gabonensis*, 2:1). *Dioscorea rotundata*, *Dioscorea dumentorum* and *Manihot esculenta* have respective molar ratios of Ca:Phy 1.8, 2.5 and 1.4 while the respective [ca] [Phy]/[Zn] molar ratios were 0.50, 0.54 and 0.62. These results suggest that the bioavailability of zinc in the Nigerian diet may be low due to the high phytate content of the staple foods.

1. Introduction

Phytic acid (phytate), is widespread in plant seeds and/or grains (O'Dell, 1979), roots and tubers (McCance & Widdowson, 1935), nucleated erythrocytes of birds and turtles (Oshima, Taylor & Williams, 1964) and organic soils (Dyer, Wrenshall & Smith, 1940). It is a chelating agent for cations as well as phosphorus in many seeds (Cosgrove, 1966).

The importance of a foodstuff as a source of dietary zinc depends on both the total zinc content and the level of other constituents in the diet that affect zinc bioavailability. Phytate may reduce the bioavailability of dietary zinc by forming insoluble mineral chelates at a physiological pH (Oberleas, 1983). The formation of the chelates depends on relative levels of both zinc and phytic acid (Davies & Olpin, 1979). Hence, the phytate:Zn molar ratio is considered a better indicator of zinc bioavailability than total dietary phytate levels alone. The critical phytate:Zn molar ratio may also depend on dietary calcium levels. A kinetic synergism exists between the calcium and zinc ions resulting in a Ca:Zn:Phy complex which is less soluble than phytate complexes formed by either ion alone (Oberleas, 1983). Ellis, Kelsay, Reynolds, Morris, Moser & Frazier (1987) suggested that the critical values of Phy:Zn and Phy×Ca:Zn are greater than 10 and greater than 200, respectively. Staple diets having such high ratios had been suggested to be associated with increased relative risk of deficiency (Cossack & Prasad, 1983; Bindra, Gibson & Thompson, 1986; Morris, Ellis, Steels & Moser, 1988; Kirksey, Harrison, Galal, McCabe & Wachs, 1992). These influences are of importance in the evaluation of the recommended dietary allowances (RDA) of Zn. Unfortunately, only limited data are available on the critical Phy:Zn and Ca×Phy:Zn ratios associated with decreased zinc bioavailability for human diets.

Studies have assayed the phytate content of some Nigerian foodstuffs using a phytate–iron precipitation method (Mbofung, Atinmo & Omololu, 1984; Ologhobo & Fetuga, 1984; Aremu, 1988) which was not able to detect phytate at concentrations below 0.1%. Harland and Oberleas (1986) determined phytate using

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a more selective and sensitive AOAC-approved method. Studies investigating the significance of the Phy:Zn and Ca*phy:Zn interaction for human zinc status are limited, in part because information on the zinc and phytate content of foods is not available. Consequently, we have analysed the calcium, phytate and zinc contents of 35 representative raw and processed foods consumed in Nigeria, calculated the corresponding Phy:Zn, Ca:Phy and Ca×Phy:Zn molar ratios of these foods. The foods under study were legumes, cereals, spices and tubers/roots.

2. Materials and methods

2.1. Materials

Samples were purchased at Oba market (Ado-Ekiti, Ekiti State, Nigeria). The samples were then grouped under their major headings: Group A (legumes), Group B (cereals), Group C (apices) and Group D (tubers/roots); details of these groupings are in Table 1.

Shells were removed from the cereal grain and the tubers/roots were peeled before analyses. The preparation of fermented maize and guinea corn followed the steps reported by Harland, Oke and Felix-Phipps (1988) while the preparation of cassava flour and fermented cassava (gari) followed the traditional method. The preparation of fermented African locust bean followed the steps enumerated by Odunfa (1986). The samples were then analysed as purchased/processed.

2.2. Determination of phytate

Phytate was quantified using the method described by Harland and Oberleas (1986). The blank was also prepared as described by Harland and Oberleas. The colorimeter used was a Spectronic 20 (Gallenkamp, UK). The amount of phytate in the sample was calculated as hexaphosphate equivalents using the formula:

Phytate, mg/g sample = "mean K" × A × 20/(0.282 × 1000) where A = absorbance; "mean K" = std P(μg)/A/n (stds); phytate = 28.2% P.

2.3. Determination of moisture and minerals

Moisture was determined by the method of the Association of Official Analytical Chemists [(AOAC), 1990] in all the food samples.

The minerals (Ca and Zn) were analysed from solutions obtained by first dry-ashing the samples at 525°C and dissolving the ash in deionised water with a few drops of concentrated hydrochloric acid. The minerals were determined by means of an atomic absorption spectrophotometer (Buck Scientific Inc., Model 200A/210, Connecticut, 1993).

2.4. Statistical analyses

All our results for Ca, Zn and Phy were reported as m/100 g dry matter (DM). The Phy:Zn, Ca:Phy and Ca×Phy:Zn values were calculated according to the method of Wyatt and Triana-Tejas (1994). Mean, standard deviation and coefficients of variation percent were also calculated (Steel & Torrie, 1960). Z-scores were calculated but converted to T-scores (to eliminate minus signs from Z-scores) (Alonge, 1989) to determine the status of each value versus the mean group value per group for Ca, Zn, Phy, Phy:Zn, Ca:Phy and Ca×Phy:Zn in all the foods.

3. Results and discussion

The scientific and vernacular names of the Nigerian foods analysed are shown in Table 1. The DM values of the foods analysed are shown in Table 2. The Ca and the Zn levels (mg/100 g DM) of the various samples are shown in Table 2.

The Phy values (mg/100 g DM) are shown in Table 2. The levels of Phy in legumes ranged from 14.0 to 344, the levels ranged from 112.0 to 287 in cereals; levels in spices ranged from 35.0 to 184 and 0.0 to 107 in tubers/roots. Literature comparison showed that our results in legumes were much lower than the levels reported (520–1410 mg/100 g wt.) in the legumes from Malawi (Ferguson, Gibson, Thompson, Ounpuu & Berry, 1988), lower than the levels reported in legumes (653±5 −797±2 mg/100 g dry wt.) by Harland et al. (1988) and 695±9−990±2 mg/100 g dry wt. (Harland & Oberleas, 1987) but close to the legume phytate levels (251–47O mg/100 g dry wt.) reported by Oke (1965). Our legume phytate levels were also lower than the phytate levels reported in various varieties of cowpea, lima bean and soybean (Ologhobo & Fetuga, 1984). The phytate level in our whole grain maize was 149 mg/100 g DM while it is reported to range from 84±18−2517±14 mg/100 g dry wt. (Harland et al., 1988) and to be 539 mg/100 g (Oke, 1965) and 129 mg/100 g (Harland & Oberleas, 1987). The Phytate level in our fermented maize sample (*ogi*) was 188 mg/100 g DM while Harland et al., (1988) reported a level of 449±22 mg/100 g dry wt. for kenkey (another maize fermented product).

The importance of *ogi* in the Nigerian diet calls for proper monitoring of the fermentation process since the process appears to enhance the increase of phytate in fermented maize flour (Harland et al., 1988). The phytate level in whole grain guinea corn was 119 mg/100 g while its fermented variety contained 112 mg/100 g as reported for our samples but the level of phytate in Malawi guinea corn was 490 mg/100 g (Ferguson et al., 1988). The only literature available for phytate level in spices is for okro which was 286±4 mg/100 g (Harland

Table 1
Scientific and vernacular names of the Nigerian foods analysed

Major food group		Common name	Vernacular name (Y)[a]	Scientific name
Legumes (A)				
1.	A_{11}	Soya bean	Soya	*Glycine max* Merr.
2.	A_{12}	Common bean (brown)	Peu	*Phaseolus vulgaris* L.
3.	A_{13}	African yam bean	Otili	*Sphenostylis stenocarpa* Hams
4.	A_{14}	Lima bean (white)	Ere	*Phaseolus lunatus* L.
5.	A_{15}	Lima bean (brown)	Ere	*Phaseolus lunatus* L.
6.	A_{16}	Pigeon pea (brown)	Waken kurawa	*Cajanus cajan* Druce
7.	A_{17}	Pigeon pea (white)	Waken kurawa	*Cajanus cajan* Druce
8.	A_{21}	Groundnuts	Epa	*Arachis hypogaea* L.
9.	A_{22}	Black trimed melon	Baara	*Colocynthis citrullus* (L.) O. Ktze.
10.	A_{23}	Elongated melon	Too	*Citrullus utilissim* L.
11.	A_{24}	Rounded melon	Baara	*Citrullus lunatus* L.
12.	A_{31}	African locust bean	Irugba	*Parkia filicoidea* Welw.
13.	A_{32}	African locust bean[b]	Irugba	*Parkia filicoidea* Welw.
Cereals (B)				
14.	B_{11}	Wheat	–	*Triticum aestivum*
15.	B_{12}	Rice	Iresi	*Oryza sativa* L.
16.	B_{13}	Millet	Gero	*Pennisetium typhoides* Stapf and Hubbard
17.	B_{21}	Maize	Agbado	*Zea mays* L.
18.	B_{22}	Maize flour[b]	Ogi	*Zea mays* L.
19.	B_{31}	Guinea corn	Oka-baba	*Sorghum bicolor* Pers.
20.	B_{32}	Guinea corn[b]	Oka-Baba	*Sorghum bicolor* Pers.
Spices (C)				
21.	C_{11}	Bell pepper	Tatase	*Capsicum annum* L.
22.	C_{12}	Cherry pepper	Rodo	*Piper nigrum* L.
23.	C_{21}	Okro	Ila	*Hibiscus esculentus* L.
24.	C_{22}	Tomato	Tomati	*Lycopersicon lycopersicum* (L.) Kerst
25.	C_{23}	Onion	Alubosa	*Allium cepa* L.
26.	C_{34}	Sugar nut	Apon	*Irvingia gabonensis L*
Tubers/roots (D)				
27.	D_{11}	Red cocoyam	Koko pupa	*Colocasia esculenta* Schott.
28.	D_{12}	White cocoyam	Koko funfun	*Colocasia esculenta* Schott.
29.	D_{21}	Yellow yam	Olo	*Dioscorea cayensis* Lam.
30.	D_{22}	White yam	Isu funfun	*Dioscorea rotundata* Poir.
31.	D_{23}	Water yam	Ewura	*Dioscorea alata* L.
32.	D_{32}	Trifoliate yam (yellow)	Esuru pupa	*Dioscorea dumentorum* Pax.
33.	D_{32}	Trifoliate yam (white)	Esuru funfun	*Dioscorea dumentorum* Pax.
34.	D_{41}	Cassava flour	Ege	*Manihot esculenta* Crantz.
35.	D_{42}	Cassava[b]	Gari	*Manihot esculenta* Crantz.

[a] Y = Yoruba
[b] Fermented samples of corresponding food

et al., 1988) and 120 mg/100 gin our current report. The phytate level in yellow yam was 452 mg/100 g DM while it was 694 mg/100 g DM in white yam. Both sample phytate levels were higher than literature values, which were 287 mg/100 g (yellow yam) and 317 mg/100 g (white yam) (Akindahunsi & Oboh, 1998) while the following values were further reported for white yam (mg/100 g); 29±9 (Harland et al., 1988), 196 (Oke, 1965) and 193 (Harland & Oberleas, 1987). Harland et al. reported 282±2 mg/100 g and Oke also reported 337 mg/100 g for cocoyam. The phytate levels in cassava flour and its fermented variety (*gari*) in our results were 530 mg/100 g DM and 355 mg/100 g DM, respectively while literature values were 123±9 mg/100 g (*gari*) and 100±5 mg/100 g (cassava flour) (Harland et al., 1988); 0.0 mg/100 g (*gari*) and 268 mg/100 g (cassava flour) (Oke, 1965), and Ferguson et al. (1988) reported 160 mg/100 g phytate level in cassava.

Oke (1965) reported that there was no phytate in onions. As shown in Table 2, we found phytate in virtually all foods of plant origin tested (except cocoyam). Oberleas (1983) reported that, depending upon processing, whole maize is relatively low in phytate compared with other grains (de Boland, Garner & O'Dell, 1975); our data indicated otherwise.

It was previously believed that, during fermentation, the enzyme phytase hydrolysed the endogenous phytate, and that there were not significant levels of phytate in fermented foods. As shown in Table 2, such may not always be the case (Harland et al., 1988). The results of

Table 2
Concentration of Zn, Ca, phytate and calculated phytate:Zn, Ca:phytate and [Ca] [Phyte]/[Zn] molar ratios of the Nigerian food samples analysed[a,g]

Sample	Dry matter (%)	Zn (mg/100 g)	Ca (mg/100g)	Phy[f] (mg/100g)	Phy/Zn[b]	Ca/Phy[c]	$\frac{[Ca][Phy]}{[Zn]}$[d]
A_{11}	85.1	2.00e	43.6f	157	8.0g	4.5h	0.09i
A_{12}	81.1	1.94e	41.2f	287	14.3g	2.4h	0.15i
A_{13}	83.7	1.31e	42.7f	14	1.1g	53.5h	0.01i
A_{14}	86.5	1.0e	30.9f	120	9.0g	4.3h	0.07i
A_{15}	88.0	0.8e	28.7f	251	38.0g	1.9h	0.27i
A_{16}	86.0	0.6e	33.1f	302	46.0g	1.8h	0.38i
A_{17}	83.8	1.2e	43.0f	310	23.5g	2.28h	0.25i
A_{21}	90.2	0.9e	32.2f	54	8.0g	10.0h	0.06i
A_{22}	93.3	0.6e	30.0f	218	33.0g	2.3h	0.25i
A_{23}	91.3	0.8e	30.3f	243	37.0g	2.1h	0.28i
A_{24}	90.8	0.7e	33.4f	120	18.0g	4.6h	0.15i
A_{31}	79.4	1.1e	44.8f	344	26.0g	2.2h	0.29i
A_{32}	94.9	0.6e	42.3f	74	11.0g	9.6h	0.12i
B_{11}	86.4	0.8e	30.1f	287	43.0g	1.7h	0.23i
B_{12}	85.6	0.7e	27.1f	189	29.0g	2.3h	0.20i
B_{13}	87.6	0.7e	17.7f	220	33.0g	1.3h	0.15i
B_{21}	85.9	1.4e	49.2f	149	11.5g	5.4h	0.14i
B_{22}	39.4	1.4e	45.1	188	14.0g	4.0h	0.16i
B_{31}	86.6	1.7e	41.5f	119	6.0g	5.8h	0.06i
B_{32}	41.2	1.8e	34.7f	112	5.7g	5.1h	0.05i
C_{11}	12.2	4.9e	144.0	90	1.8g	25.6h	0.06i
C_{12}	31.8	1.6e	32.7	35	2.5g	16.4h	0.02i
C_{21}	15.0	4.4e	139.5	120	2.6g	19.3h	0.09i
C_{22}	6.2	4.0e	187.4	65	1.7g	46.8h	0.08i
C_{23}	14.2	3.3e	147	49	1.4g	52.3h	0.05i
C_{34}	95.2	0.3e	17.0	184	28.0g	1.5h	0.12i
D_{11}	43.3	2.3e	96.8	0	–[e]	–	–
D_{12}	17.4	2.4e	89.9	0	–	–	–
D_{21}	40.9	1.7e	36.7	452	22.7g	1.4h	0.21i
D_{22}	38.1	2.3e	77.1f	694	26.3g	1.8g	0.50i
D_{23}	34.2	1.4e	38.2	269	21.5g	2.3h	0.05i
D_{31}	14.6	7.1e	155	1021	14.1g	2.5h	0.54i
D_{32}	25.7	4.0e	92.3	1070	27.0g	1.4h	0.62i
D_{41}	45.3	3.5e	53.3f	530	16.0g	1.7h	0.21i
D_{42}	48.2	2.8e	37.7	355	13.5g	1.7h	0.13i

[a] Mean of duplicate determinations on dry matter basis.
[b] (mg of Phy/MW (molecular weight) of Phy:mg of Zn/MW of Zn.
[c] (mg of Ca/MW of Ca:mg of phy/MW of phy).
[d] (mol/kg Ca) (mol/kg Phy)/(mol/kg Zn).
[e] –Not determined.
[f] Phytate content calculated by assuming that it contains 28.2% phosphorus.
[g] e,f,g,h,i: Data points that share common letters have their T-scores greater than the group mean value within their group.

this study indicated that the phytate content may be increased on fermenting maize, may be unaltered in fermented guinea corn but significantly reduced in fermented cassava and African locust bean. The level of phytate was reduced by 50.0% in fermented African locust bean (Odunfa, 1986).

Oberleas and Harland (1981) showed that foods with a molar ratio of Phy:Zn less than 10 showed adequate availability of Zn and problems were encountered when the value was greater than 15. In Table 2, the Phy:Zn ratios are shown for the foods analysed. In the legume samples studied, only soya bean, common bean, African yam bean, lima bean (white), groundnut and fermented locust bean have Phy:Zn values less than 15, which could indicate low Zn availability in most of the legumes. Rice, wheat and millet have Phy:Zn ratios greater than 15 among the cereals, which means 57.1% of our cereal samples would have their Zn available. All the spice samples have low Phy:Zn values with the exception of sugar nut, indicating that Zn is probably more available in spices. in tuber/roots, only cocoyam (red and white), yellow bitter yam and *gari* have Phy:Zn values less than 15. This means that the Zn in most of the tubers/roots samples studied may not be available.

Franz, Kennedy and Fellers, (1980) determined molar ratios in corn, cooked and raw, finding ratios of 30 and 33, respectively. These same authors demonstrated a lower availability of Zn in rats when fed with foods of high molar ratios of Phy:Zn.

In the report of Morris and Ellis (1981), growth of rats was not depressed when cereals with Phy:Zn molar ratios of 15 or lower were the dietary zinc source, but growth was significantly depressed when cereals with Phy:Zn molar ratios of 24 and greater were the zinc source. When the protein source is soy, the critical ratio may be lower than 12–15 (Oberleas & Prasad, 1976) or it may be higher if the dietary zinc is several times the minimum requirement for growth (Morris & Ellis). In human studies, Phy:Zn molar ratios of 15:1 have also been associated with reduced zinc bioavailability (Turnlund, King, Keyes, Gong & Michel, 1984). O'Dell, Boland and Koirtyohann (1972) found the zinc in corn to be more bioavailable than the zinc in rice or wheat; our results agreed with this report, based on the Phy:Zn in the foods: 430 (wheat), 29.0 (rice), 33.0 (millet) and 11.5 (maize). Many of our Phy:Zn values exceed 15, and exceeded levels reported for an unleavened Middle Eastern bread, tanok (18.0) (Reinhold, 1973). The latter was implicated as an etiological factor in the first cases of human zinc deficiency described in the Middle East (Prasad, Miale, Farid, Schulert & Sandstead, 1963). The high Phy:Zn molar ratio in most of the Nigerian diets may have serious implications, moreover, because animal products, which are the alternative sources of zinc are sold at unaffordable prices, particularly to the rural Nigerians (Adeyeye, 1996).

Wise (1983) suggested that the solubility of the phytates and that the proportion of Zn bound in a mineral complex in the intestines depend on the levels of Ca. In his model, phytate precipitation is not complete until dietary Ca:Phy molar ratios attain a value of approximately 6:1 and phytate precipitation is incomplete, so that some of the dietary Zn remains in solution. The proportion remaining in solution increases with decreasing Ca:Phy molar ratios (Wise).

In our results, all tubers/roots and cereals have Ca:Phy levels less than 6 and this same observation was also noted for legumes with the exception of African yam bean, groundnuts and fermented African locust bean. In spices, only the sugar nut Ca:Phy level was less than 6. These results showed that Ca content of the Nigerian diets may be sufficient to promote a phytate-induced decrease in zinc bioavailability (Ferguson et al., 1988). Ferguson et al. and Ferguson, Gibson, Thompson and Ounpuu (1989) showed that the molar ratio varies with different foods and recommended that this value be used in conjunction with other data to explain the availability of Zn using the Ca:Phy ratio.

In Table 2, we presented the values for the molar ratios of [Ca] [Phy]/[Zn] i.e. (Ca×Phy:Zn). Ellis et al. (1987) and Davies and Warrington (1986) indicated that the ratio of Ca×Phy:Zn is a better predictor of Zn availability and said that, if the value were greater than 0.50 mol/kg, there would be interferences with the availability of Zn. In our results, Ca×Phy:Zn values were greater than 0.50 mol/kg in yellow bitter yam (0.54 mol/kg) and white bitter yam (0.62 mol/kg) while other Ca×Phy:Zn values were lower than or equal to 0.50 mol/kg. That is to say, using this indicator, Zn availability would be affected in bitter yam (yellow and white).

The statistical results for all the samples are shown in Table 3. The legumes are divided into three groups of A_{11}–A_{17} (beans), A_{21}–A_{24} (oil seeds) and A_{31}–A_{32} (African locust bean). In the group A_{11}–A_{17} the Ca mean value was 37.6±6.5 with a coefficient of variation percent (CV%) of 17.2, Zn value was 1.3±0.5 and CV% of 41.7; phy value was 206±112 with CV% of 54.4, Phy:Zn value was 19.9±16.7 with CV% of 83.4, Ca:Phy value was 10.1±19.2 with CV% of 190 and Ca×Phy:Zn value was 0.2±0.1 with CV% of 76.5. The results of the oil seeds (A_{21}–A_{24}) followed the trends of A_{11}–A_{17} in the mean, standard deviation and CV% in Ca, Zn, phy; Phy:Zn and Ca×Phy:Zn. It should be noted that serial number 26 was included in the oil seeds group (C_{31}) because the sugar nut is regarded as an oil seed (69.6±0.6 g/100 g crude fat dry wt.) (Oshodi and Ipinmoroti, 1990). The African locust bean (A_{31}–A_{32}) had the lowest CV% (4.1) for Ca while the other CV% values for Zn, Phy, Phy:Zn, Ca:Phy and Ca×Phy:Zn were comparatively higher. Table 2 shows that only fermented African locust bean T-score value were below the group mean within its group for Zn level; lima bean (brown) T-score values below the group mean value (within its group) for Ca and no phy T-score value was up to the group mean value among the legumes.

The cereals are in the B group (Table 1**).** They are in the groups B_{11}–B_{13} (whole grain kernel), B_{21}–B_{22} (maize and *Ogi*) and B_{31}–B_{32} (guinea corn and *oka-baba*). In the cereals, all the CV% were low for Ca, Zn, Phy, Phy:Zn, Ca:Phy and Ca×Phy:Zn, and this shows that the various parameter values were homogeneous and that the nutritional characteristics may not be very different among the cereals under review. Table 2 shows that the Ca level of *ogi* was not different from members of its group and no cereal was different from its group as shown by their T-scores.

The spices are in group C and they are in sub groups C_{11}–C_{12} (pepper), C_{21}–C_{23} (Okro, tomato and onion, respectively) and C_{31} (sugar nut). Sugar nut was different from the other group members in its Ca content because its T-score value was greater than the group mean but no phy level was different (T-score) among the spices. All the Zn, Phy:Zn, Ca:Phy and Ca×Phy:Zn levels have their T-score values greater than their corresponding mean values showing their high variability for those values.

Table 3
Mean ($\bar{X}$), standard deviation (S.D.) and coefficient of variation percent (CV%) of Zn, Ca, Phy, Phy:Zn, Ca:Phy and [Ca] [Phy]/[Zn] of the food groups analysed

		Ca[a]	Zn[a]	Phy[a]	Phy:Zn	Ca:Phy	$\frac{[Ca][Phy]}{[Zn]}$
Group A: legumes							
A_{11}–A_{17} (beans)	$\bar{X}$	37.6	1.3	205.9	20.0	10.1	0.17
	S.D.	6.5	0.5	112.0	16.7	19.2	0.13
	CV%	17.2	41.7	54.4	83.4	190	76.5
A_{21}–A_{24} and C_{34} (Oil seeds)	$\bar{X}$	28.6	0.7	164	24.8	4.1	0.17
	S.D.	6.6	0.2	76.8	11.8	3.5	0.09
	CV%	23.2	31.3	46.9	47.5	85.8	52.9
A_{31}–A_{32} (Locust bean)	$\bar{X}$	43.6	0.8	209	18.5	5.9	0.21
	S.D.	1.8	0.4	191	10.6	5.3	0.12
	CV%	4.1	48.8	91.4	57.4	89.8	57.1
Group B: cereals							
B_{11}–B_{13} (whole seed kernel)	$\bar{X}$	25.0	0.7	232	35.0	1.8	0.19
	S.D.	6.5	0.04	50.1	7.2	0.5	0.04
	CV%	25.9	5.6	21.6	20.6	28.3	21.1
B_{21}–B_{22} (maize)	$\bar{X}$	47.1	1.4	169	12.8	4.7	0.15
	S.D.	2.9	0.02	27.6	1.8	1.0	0.01
	CV%	6.2	1.4	16.4	13.9	20.3	6.7
B_{31}–B_{32} (guinea corn)	$\bar{X}$	38.1	1.8	116	5.8	5.5	0.06
	S.D.	4.9	0.13	5.0	0.2	0.5	0.01
	CV%	12.7	7.4	4.3	3.9	8.6	16.7
Group C: spices							
C_{11}–C_{12} (pepper)	$\bar{X}$	88.4	3.3	62.5	2.1	21.0	0.04
	S.D.	78.6	2.4	38.9	0.5	6.5	0.03
	CV%	89.0	72.9	62.2	24.9	31.1	75.0
C_{21}–C_{23} (okro, tomato, onion)	$\bar{X}$	158	3.9	78.0	1.9	39.5	0.07
	S.D.	25.8	0.6	37.2	0.6	17.7	28.6
	CV%	16.4	14.6	47.7	32.5	44.7	28.6
Group D: tubers/roots							
D_{11}–D_{12} (cocoyam)	$\bar{X}$	93.4	2.4	0.0	–[b]	–	–
	S.D.	4.8	0.13	0.0	–	–	–
	CV%	5.2	5.5	0.0	–	–	–
D_{21}–D_{23} (yam)	$\bar{X}$	50.7	1.8	472	23.1	1.8	0.25
	S.D.	22.9	0.5	213	2.9	0.5	0.23
	CV%	45.2	27.0	45.2	12.5	26.8	92.0
D_{31}–D_{32} (bitter yam)	$\bar{X}$	124	5.5	1046	20.6	2.0	0.58
	S.D.	44.1	2.2	34.7	9.1	0.8	0.06
	CV%	35.7	39.4	3.3	44.4	38.8	10.3
D_{41}–D_{42} (cassava)	$\bar{X}$	45.5	3.1	443	14.8	1.7	0.17
	S.D.	11.0	0.5	124	1.8	0.06	0.06
	CV%	24.3	16.7	28.0	12.0	3.5	35.3

[a] Mean values are in mg/100 g.
[b] Not determined.

Group D is composed of the tubers/roots which are D_{11}–D_{12} (cocoyam), D_{21}–D_{23} (yam), D_{31}–D_{32} (bitter yam) and D_{41}–D_{42} (Cassava). The CV% for cocoyam was low, ranging from 5.2–5.5 for Ca and Zn levels, respectively. The Zn T-score values for cocoyam were also on the high side. The heterogeneous nature of the values of Ca, Zn, Phy, Phy:Zn, Ca:Phy and Ca×Phy:Zn for D_{21}–D_{23}, D_{31}–D_{32} and D_{41}–D_{42} samples are shown by their CV%. The T-score values also showed that all the Zn values were highly different for D_{21}–D_{42}, only white yam and cassava flour have their T-score values greater than the mean value in Ca levels among their groups while all Phy:Zn, Ca:Phy and Ca×Phy:Zn levels have greater T-score values than their corresponding group mean for D_{21}–D_{42}.

Zinc deficiency has been shown to be the cause of dwarfism and hypogonadism among adolescents from the lowest social classes of Egypt (Prasad, 1984). The data presented here cover a broad range of foods consumed in Nigeria and appear to form baseline information for levels of Phy, Phy:Zn, Ca:Phy and Ca×Phy:Zn for most of the foods since literature information is scarce. Going by the work of Hussein and Bruggeman (1997), we are advocating that the level of research devoted to the improvement of protein intake in Nigerian foods should also include the study of Zn availability in

foods and the assessment of Zn bioavailability from Nigerian diets in human balance biological experiments.

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