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Chemical Estimation of Iron, Zinc, Copper and Phytic Acid in Selected Foodstuffs

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ABSTRACT

Iron, zinc, copper and phytic acid were determined in a variety of Nigerian staple foodstuffs; the values ranged from $13{\cdot}0 \pm 2{\cdot}05$ *to* $45{\cdot}0 \pm 1{\cdot}70$, $1{\cdot}35 \pm 0{\cdot}17$ *to* $6{\cdot}93 \pm 0{\cdot}61$, $1{\cdot}10 \pm 0{\cdot}07$ *to* $6{\cdot}73 \pm 0{\cdot}14$ *and* $19{\cdot}2 \pm 1{\cdot}18$ *to* $139 \pm 3{\cdot}26$ *mg/100 g dry matter (DM), respectively. The role of phytic acid in reducing the bioavailability of these elements in the typical Nigerian diet is discussed.*

INTRODUCTION

Foodstuffs of vegetable origin constitute the bulk of the diet in many developing countries, including Nigeria (USDA, 1962). These foodstuffs are normally consumed in quantities which contain most of the essential mineral elements in excess of individual requirements for these elements (Sayers *et al.*, 1974). However, there is ample evidence in support of the poor bioavailability of some of these elements, including iron, zinc and copper, especially from vegetable origin (Underwood, 1977).

Many investigators have attributed the poor bioavailability of certain of the elements mainly to phytates (Sayers *et al.*, 1974). Some information is available on the phytate contents of some Nigerian foodstuffs (Chakraborty & Eka, 1978), but there has been no indication as to whether or not the phytate levels normally found in these foodstuffs are high enough to pose any nutritional problem. The results reported in this paper concern the analyses of iron, zinc, copper and phytic acid in raw and semi-processed foodstuffs which are popularly consumed in Nigeria. These data are intended to serve as prerequisites for further investigating the role of phytic acid in the bioavailability of these elements in the 'average' Nigerian diet.

EXPERIMENTAL

Collection of samples

Three examples of each foodstuff were purchased from local markets with the exception of semovita, a single batch of which was purchased from a local flour mill. Sub-samples of each type of foodstuff were either cooked, roasted or fried in palm oil under conditions similar to the normal household processing. The raw and processed sub-samples were then dried in an oven at 60°C, milled and stored in air-tight polythene bottles until analyzed.

Analysis of samples

A 1-g portion of each sub-sample was used for the determination of iron, copper and zinc (AOAC, 1975). Each sample was digested with a 5:1 (v/v) mixture of concentrated nitric acid and 65% perchloric acid. The concentration of each element was then determined in the digest by atomic absorption spectrophotometry (SP 2900 Pye Unicam model).

The method of Mclane & Widdowson (1953) was used for the determination of phytic acid in the cooked samples. A 10-g sample was extracted with 100 ml of 0·05 N hydrochloric acid. The extract was neutralized with dilute sodium hydroxide, treated with 4 ml of a 0·5 mg/ml ferric chloride solution and the ferric phytate collected by centrifugation. The phytate was then dissolved in 2 ml distilled deionized water over a boiling water bath and treated with 2 ml of a 2% solution of sodium hydroxide.

The resultant sodium phytate solution was filtered and the ferric hydroxide precipitate was washed thrice with hot distilled deionized water, and the washings recovered along with the filtrate into a 25-ml conical flask. To the filtrate was added 1 ml of concentrated sulphuric acid and 1 ml of 65% perchloric acid, with subsequent digestion on a hot plate until a clear solution was obtained. The digest was neutralized to phenolphthalein using a 40% sodium hydroxide solution. Phytate phosphorus was estimated against standards in 5-ml aliquots of the digest by colorimetry at 620 nm (Spectronic 20A model).

The various analyses were carried out in triplicate.

RESULTS AND DISCUSSION

The results of elemental analysis are shown in Table 1. The values for iron ranged from 13·0 ± 2·05 mg/100 g DM in raw semovita to 45·0 ± 1·70 mg/100 g DM in *foo-foo*. For zinc, the lowest value of 1·35 ± 0·17 was found in raw unripe plantain, whereas the highest value of 6·93 ± 0·61 was in raw cassava. Raw ripe plantain contained the least copper (1·10 ± 0·07 mg/100 g DM), while *foo-foo* had the highest (6·73 ± 0·14 mg/100 g DM).

Table 2 shows the data on phytic acid found in the cooked samples of food. All the samples had relatively low levels (less than 50 mg/100 g DM) of phytic acid with the exception of cowpea (135 ± 0·42 mg/100 g DM) and groundnut (139 ± 3·26 mg/100 g DM).

It has been observed that the diet of most people in Nigeria, especially the southern part (and various other parts of the world), consists mainly of vegetable materials such as tubers and cereal grains (USDA, 1962; Ball, 1966). It is to be expected, therefore, that such vegetable foodstuffs would constitute the most significant suppliers of nutrients, including mineral elements, to humans living in these regions. As has been shown in Table 1, most of the samples analyzed were found to be relatively high in iron in particular and, to a lesser extent, zinc and copper. In spite of the relatively high iron in the diet of most Nigerians, for instance, there is evidence of nutritional iron and zinc deficiencies in humans (Mbofung & Atinmo, 1980). The evidence suggests that the humans concerned are either not consuming enough food to meet their nutritional needs and/or that these nutrients are not readily available from the normal diet. Unfortunately, in a place like Nigeria, there is a scarcity of reliable data and quantitative information on consumption and on chemical analysis of the foods actually eaten. It is, therefore, difficult to ascertain which of the factors mentioned above is responsible for the nutritional deficiencies of these minerals which have been observed.

It is widely recognized, however, that an interplay of various dietary factors may reduce the bioavailability of divalent elements such as iron, zinc and copper, and prominent among these factors is phytic acid (Sayers *et al.*, 1974; Davidson *et al.*, 1975; Underwood, 1977). Unfortunately, no information was found in the literature as to the range of phytic acid levels present in the 'average' Nigerian diet and whether the levels normally present in the diet could be considered toxic to humans. In fact, the data

TABLE 1
Moisture, Iron, Zinc and Copper Content of Foodstuffs

Foodstuff	*Moisture* (%)	*Iron* (*mg/100 g DM*)	*Zinc* (*mg/100 g DM*)	*Copper* (*mg/100 g DM*)
Cassava (*Manihot utillissima*)				
Raw	10·93 ± 0·27[e]	36·7 + 1·44[e]	6·93 ± 0·61[e]	3·73 ± 0·34[e]
Foo-foo[a]	9·33 ± 0·03	45·0 ± 1·70	4·73 ± 0·39	6·73 ± 0·14
Garri[b]	10·91 ± 0·33	29·7 ± 2·33	2·33 ± 0·05	1·56 ± 0·29
Yam (*Dioscorea ayennensis*)				
Raw	5·66 ± 0·26	14·7 ± 2·68	1·50 ± 0·07	2·30 ± 0·98
Cooked	11·48 ± 0·09	21·3 ± 0·54	6·53 ± 1·65	4·26 ± 1·59
Pounded	8·20 ± 0·06	19·7 ± 0·27	3·80 ± 0·18	3·56 ± 0·46
Cowpea (*Vigna unguiculata* Walp)				
Raw	10·51 ± 0·03	18·3 ± 1·19	3·73 ± 0·05	3·63 ± 1·91
Cooked	6·76 ± 0·08	18·7 ± 0·72	6·33 ± 0·28	2·16 ± 0·07
Moi-moi[c]	ND	19·7 ± 3·03	6·60 ± 0·00	2·66 ± 0·29
Semovita[d]				
Raw	12·46 ± 0·15	13·0 ± 2·05	2·03 ± 0·40	1·16 ± 0·13
Cooked	7·35 ± 0·05	15·3 ± 1·96	2·20 ± 0·48	1·36 ± 0·07
Plantain (*Musa paradisiaca*)				
Unripe: Raw	5·71 ± 0·07	13·3 ± 0·27	1·35 ± 0·17	1·50 ± 0·19
Cooked	8·03 ± 0·13	23·7 ± 4·95	4·00 ± 1·39	3·63 ± 2·11
Fried	10·40 ± 0·16	16·3 ± 0·98	1·70 ± 0·61	2·31 ± 1·03
Ripe: Raw	5·00 ± 0·08	19·0 ± 0·47	2·30 ± 0·45	1·10 ± 0·07
Cooked	10·58 ± 0·13	21·0 ± 1·24	4·46 ± 0·19	4·06 ± 0·58
Rice (*Oryza sativa*)				
Raw	12·55 ± 0·14	29·0 ± 0·47	1·60 ± 0·16	1·33 ± 0·19
Cooked	1·50 ± 0·08	14·7 ± 1·36	1·73 ± 0·07	1·16 ± 0·11
Groundnut (*Arachis hypogaea*)				
Raw	4·86 ± 0·08	19·0 ± 3·39	2·95 ± 0·11	1·60 ± 0·00
Cooked	3·58 ± 0·13	15·7 ± 1·44	2·46 ± 0·09	3·53 ± 1·50
Roasted	5·71 ± 0·13	20·7 ± 1·90	2·96 ± 0·03	1·76 ± 0·22

[a] Fermented, grated and cooked cassava paste.
[b] Grated, fermented cassava granules, cooked.
[c] Wet-milled cowpea paste, mixed with palm oil and cooked.
[d] Mechanically dehulled dry-milled wheat.
[e] Each value represents mean ± SEM.
ND, not determined.

TABLE 2
Phytic Acid and Total Phosphate Content of Cooked Foodstuffs

Foodstuff	*Phytic acid (mg/100 g DM)*	*Total phosphate (mg/100 g DM)*	*Phytate total phosphate (%)*
Garri	19·2 ± 1·18[a]	50·0 ± 0·00[a]	38·4
Yam	48·3 ± 0·45	100 ± 0·00	48·3
Cowpea	135 ± 0·42	380 ± 16·32	35·5
Semovita	28·0 ± 3·02	66·7 ± 9·43	42·0
Plantain			
Unripe	31·3 ± 2·04	62·7 ± 2·18	50·0
Ripe	25·7 ± 1·46	90·0 ± 2·72	48·2
Rice	34·9 ± 0·11	90·0 ± 0·00	38·8
Groundnut	139 ± 3·26	313 ± 10·89	44·3

[a] Each value represents mean ± SEM.

reported by Fairweather-Tait (1982) raise the question as to whether phytic acid *per se* is the major factor reducing the bioavailability of iron in rats or humans. It is of interest, therefore, to determine whether or not the levels of phytic acid found in Nigerian foodstuffs, such as those reported in Table 2, are capable of interfering with the bioavailability of iron, zinc or copper. One way to approach this problem is to correlate the bioavailability of the various mineral elements from the different foodstuffs with the actual levels of phytic acid found in these foodstuffs.

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