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Copper and zinc contents of Nigerian foods and estimates of the adult dietary intakes

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Abstract

Concentrations of copper and zinc were determined in 80 Nigerian food items of various classes which were obtained from the markets of Ibadan city. These consisted of leafy and fruity vegetables, tubers, fruits, meats, fish, legumes, cereals, spices, dairy products, sweeteners, fats and oils, confectioneries, canned foods and alcoholic beverages. Copper levels ranged widely from 0.06 to 13.3 mg/kg, while zinc levels ranged from 0.06 to 56.9 mg/kg in various foods. The differences in mean metal levels were found to be significant ($P=0.05$) among the various food classes. Highest levels of both metals were found to occur in legumes (Cu, 8.3±3.7 mg/kg; Zn, 29±12 mg/kg). The levels of the metals compare well with those which have been obtained in foods from studies elsewhere in the world. The dietary intakes of both metals for the adult population was found to vary with the income groups, with higher intakes being estimated for higher income groups. The estimated weighted average dietary intakes for the entire adult population were calculated to be 2.64 mg Cu/day and 15.8 mg Zn/day.

1. Introduction

Accurate and adequate food composition data are invaluable for estimating the adequacy of intakes of essential nutrients and assessing exposure risks from intake of toxic non-essential elements. In many less-developed countries such data are not readily available (Bruce & Bergstrom, 1983; Burk & Pao, 1980; Hoover & Pelican, 1984). Trace heavy metals are significant in nutrition, either for their essential nature or their toxicity. Copper and zinc are known to be essential and may enter the food materials from soil through mineralisation by crops, food processing or environmental contamination, as in the application of agricultural inputs, such as copper-based pesticides which are in common use in farms in some countries. The adult human body contains about 1.5–2.0 ppm of Cu (Kies, 1989) which is essential as a constituent of some metalloenzymes and is required in haemoglobin synthesis and in the catalysis of metabolic oxidation (Schroeder, 1973; Underwood, 1977). Symptoms of copper deficiency in humans include bone demineralisation, depressed growth, depigmentation, and gastro-intestinal disturbances, among others, while toxicity due to excessive intake has been reported to cause liver cirrhosis, dermatitis and neurological disorders (Graham & Cordano, 1976; Lucas, 1974; Somer, 1974). Zinc constitutes about 33 ppm of adult body weight and is essential as a constituent of many enzymes involved in a number of physiological functions, such as protein synthesis and energy metabolism. Zinc deficiency, resulting from poor diet, alcoholism and malabsorption, causes dwarfism, hypogonadism and dermatitis, while toxicity of zinc, due to excessive intake, may lead to electrolyte imbalance, nausea, anaemia and lethargy (Fairweather-Tait, 1988; Prasad, 1976, 1984; Valee, Wacker, Batholomay & Hoch, 1957). Considerable interest has thus been focused on the determination of the copper and zinc contents of foods, and the estimation of their dietary intakes among different groups of people.

Summaries of the composition of Nigerian foods (Oguntona & Akinyele, 1995; US Department of Health, Education and Welfare [USDHEW], 1967) generally show a sparsity of data on trace heavy metals contents. A survey of the literature reveals only a few studies of Nigerian foods for Cu and Zn contents, and these are very limited in the scope of foods surveyed (Akpanabiatu, Bassey, Udosen & Iyang, 1998; Mbofung & Atinmo, 1980; Odukoya & Ajayi, 1987; Onianwa,

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Adetola, Iwegbue, Ojo & Tella, 1999; Udoessien & Aremu, 1991). The study reported in this paper seeks to obtain more comprehensive data on the zinc and copper contents of a wider variety of Nigerian foods, for use in estimating the dietary intake of these elements in the average adult Nigerian. In doing this, about 80 different food items of various food groups which make up the daily diets of the ordinary Nigerian from the southern parts of the country were analysed. Using the results of these and other analyses, the dietary intakes of both metals have been estimated from a survey of the food consumption patterns of the various income classes of the adult population.

2. Materials and methods

Eighty different food items of the following food groups were sampled and analysed: leafy and fruity vegetables, fruits, meats and related items, alcoholic beverages, fish, cereals, legumes, tuber/tuber products, spices/seasonings, dairy products, canned processed foods, additives and sweeteners, fats and oils, and confectioneries. The samples were purchased from markets in the city of Ibadan, SW Nigeria, and were handled carefully to avoid contamination. Samples were generally analysed as purchased, in the fresh forms. Wet solid samples were first air-dried in a clean room and then ground. The ground solid samples were placed in vitreosil crucibles and dry-ashed in a muffle furnace by stepwise increase of the temperature up to 550°C over 2 h, and then leaving to ash at this temperature for a further 10 h (Crosby, 1977). A few drops of concentrated nitric acid were added to the solid as an ashing aid before ashing was commenced. The ash was dissolved with 1 M nitric acid and the solution made up to volume with the same 1 M nitric acid. Samples which could not be conveniently processed by dry ashing, e.g. oils, were wet-digested by refluxing with a 4:1 mixture of nitric acid and perchloric acid. The digest was evaporated almost to dryness and then made up with distilled water to volume. Some samples, e.g. liquid beverages, were processed by a combination of wet-digestion and dry-ashing. A large volume (about 250 ml portion) of such samples was first boiled with nitric acid in an evaporating dish till a caramelous cake was formed. This cake, in the same dish, was then ashed in the furnace, and the ash dissolved with minimal volume of 1 M nitric acid. In this way organic matter is destroyed in the sample, and a high level of concentration of the sample solution is achieved. The sample solutions were subsequently analysed for copper and zinc contents using a flame atomic absorption spectrophotometer (Buck Scientific 200A model).

Each sample was analysed in duplicate, and a blank determination was carried out with every batch of 15 samples. Grinding of dry samples was done using a porcelain mortar and pestle to avoid metal contamination from steel mills. All glassware was thoroughly cleaned by soaking overnight in 2 M nitric acid and then rinsing thoroughly with distilled water. The concentrated acids used for the digestion were of AnalaR grade, while the distilled water used was further deionised. The blank values were generally low and below the detection limits of the instrument for the metals. Stock standard solutions for the atomic absorption analyses were obtained as the commercial BDH metal standards for atomic absorption spectroscopy. Working standards were made from the stock by dilution of measured aliquots with 1 M nitric acid. Analysis was carried out at the most sensitive analytical spectral lines of the metals (Cu — 324.8 nm; Zn — 213.9 nm). Coefficients of variation for sample duplicate analysis were of the order of 3–10% for both zinc and copper determinations. A recovery study of the analytical procedure was carried out by spiking and homogenising several already analysed solid and liquid samples with varied amounts of standard solutions of the metals. The spiked samples were then processed for organic matter destruction, as was initially done for the samples, and then analysed. Average recoveries obtained were Cu, 92.6±1.3%, and Zn, 97.3±3.5%.

The statistical analysis of the data was carried out with the aid of a Jandel Scientific SigmaStat statistical package, using appropriate tools, such as the Analysis of Variance, *t*-tests, Variance ratio test, etc.

2.1. Estimation of dietary intake

In carrying out the estimate of the daily dietary intake of copper and zinc, seven research students were each required to independently carry out a survey of the average composition of the diets of adults within the city of Ibadan, which represents a typical urban settlement in southern Nigeria. The surveys were conducted over a period of 5 days by directly observing the diets, weighing some of the food items, administering questions on consumption patterns, and estimating the amounts of food ingredients in the diets based on the observed weights of foods and the methods of food preparation. The survey was carried out for all the usual meals taken in a day, which include breakfast, lunch, supper, and snacks which are usually eaten between meals. A total of 62 volunteers, made up of male and female adults in the age range 19–55 years were observed. The food samples analysed covered the range of foods and ingredients which were observed in the diets. The observations of all the investigators were then harmonised to obtain constituent formulations for several breakfasts, lunches, suppers and between-meal snacks. From the concentrations of copper and zinc which have been obtained in this study, and the results of the food consumption survey, the amounts of the metals contained in each meal were calculated. Average values were then separately calculated for the breakfast, lunch, dinner and snacks. Daily intakes were calculated as the sums of these. This method has been shown to give results which do not significantly differ from the use of food composites in total diet studies for the estimation of dietary intakes of food nutrients (Horwath, 1993; World Health Organization [WHO] 1985).

3. Results and discussion

The concentrations of copper and zinc in the individual food items are given in Table 1. Table 2 gives the mean concentrations (± S.D.) of the metals for the various food groups. The Cu levels ranged widely from a low 0.06 mg/kg in wine to a relatively high 13.3 mg/kg

Table 1
Concentrations (mg/kg) of copper and zinc in Nigerian foods

Food description	Copper	Zinc	Food description	Copper	Zinc
Leafy and fruity vegetables			Guinea corn	3.07	22.0
Cabbage	0.41	2.00	Spaghetti	2.53	3.54
Pumpkin leaves (*Telfairia occidentalis*)	0.07	3.53			
Water leaf (*Talinum triangulare*)	0.23	2.92	*Legumes*		
Lettuce	0.72	2.30	Soya beans	9.80	32.0
Bitter leaf	0.20	2.87	Beans	6.87	42.7
Ewedu (*Corchorus olitorius*)	0.13	2.87	Groundnut	4.00	14.0
Sokoyokoto (*Celosia argentea*)	0.20	3.53	Melon	12.5	28.2
Tete (*Amaranthus thunbergii*)	0.07	2.87			
Efirin (*Ocium gratissium*)	0.23	3.53	*Tubers/tuber products*		
Carrot	0.40	1.70	Yam, tuber	4.73	10.0
Tomatoes	0.36	1.00	Potato	0.72	3.00
Garden egg (*Solanum melongena*)	5.47	9.67	Cassava, tuber	4.07	7.40
Okra	6.95	2.37	Garri (fried cassava flour)	1.07	5.13
Onion	7.30	17.3			
			Spices/seasonings		
Fruits			Pepper	7.21	27.4
Mango	1.00	1.00	Garlic	4.47	27.9
Orange	2.13	2.20	Ginger	2.93	8.27
Pineapple	0.80	0.97	Locust bean (Iru)	13.3	56.9
Plantain, raw	3.94	9.00	Curry	5.33	53.7
Paw-paw	0.64	2.08	Thyme	0.40	0.20
Banana	0.95	1.50	Seasoning cube (Maggi brand)	1.40	1.07
Apple	0.25	0.16	Potash (Kawun)	2.33	0.87
Water melon	2.13	7.40			
Coconut	2.40	4.50	*Dairy products*		
Guava	1.00	2.00	Milk, evaporated	0.72	6.37
			Cheese	1.27	16.9
Meats and related items			Yoghurt	1.05	17.3
Beef	1.60	23.5	Milk, powdered	0.60	35.6
Pork	2.87	30.2			
Goat meat	3.80	40.9	*Canned processed foods*		
Snail	3.80	33.5	Sardine	1.20	5.33
Cow liver	3.80	33.5	Baked beans	0.87	2.00
Cow kidney	9.67	19.5	Canned geisha	1.07	0.33
Cow hide (Ponmo)	0.40	43.5	Corned beef	2.00	23.5
Turkey	1.27	13.5			
Chicken	1.00	2.87	*Additives and sweeteners*		
Periwinkle	12.1	22.9	Salt	2.40	2.13
Egg	1.13	6.87	Sugar	0.33	0.06
			Jam	0.67	12.2
Alcoholic beverages			Honey	0.60	36.9
Beer	0.24	0.18			
Wine	0.06	0.23	*Fats and oils*		
			Palm oil	0.68	7.53
Fish			Groundnut oil	0.40	0.67
Stock fish (Panla)	2.00	23.5	Vegetable oil	0.65	0.60
Frozen fish	1.00	18.5	Margarine	2.47	1.53
Dried fish	3.33	22.1			
Crayfish	2.67	15.5	*Confectioneries*		
			Sweets	0.60	0.27
Cereals/cereal products			Biscuits	1.93	6.87
Rice	1.53	4.93	Bread	0.60	2.93
Maize	2.33	33.4			

in locust bean (a food seasoning). Analysis of variance of the concentrations of copper in the food items indicates that the differences observed in the Cu concentrations among the groups is statistically significant (F-stat. = 3.065; F-crit. = 1.871; P = 0.05). Within each food group the Cu levels varied significantly, with the lowest variation of 27% occurring in cereals, and the highest (169%) in the fruity and leafy vegetables. Copper levels were lowest in the alcoholic beverages (0.15±0.13 mg/kg) and highest in legumes (8.3±3.7 mg/kg).

Zinc levels were generally higher in the food items than the corresponding copper levels. Zinc levels also varied widely from a low 0.06 mg/kg in sugar to a high 56.9 mg/kg in locust bean. The mean levels of Zn were also found to vary significantly among the groups (F-stat. = 4.048; F-crit. = 1.871; P = 0.05). Highest Zn levels (29±12 mg/kg) occurred in the legumes, as was the case with Cu. Similarly high levels (19–25 mg/kg) were found in meats, fish, spices and dairy products, while the lower Zn levels occurred in the beverages, fruits, fats and oils, and confectioneries.

The levels of copper and zinc found in this study of Nigerian foods compare well with levels which have been found in similar foods from various parts of the world. The Nigerian levels generally fall within the ranges for these metals all over the world. Table 3 compares the levels in some Nigerian foods from this study with those obtained from studies in the USA, Sweden, Egypt, East Asia and other Nigerian studies. Copper and zinc levels in legumes (beans) in this study are significantly higher (t-test; P = 0.05) than those obtained by Udoessien and Aremu (1991) in a previous Nigerian study.

Table 2
Average levels (mg/kg) of copper and zinc in various food groups

Food group description	Copper		Zinc	
	Mean±S.D.	Range	Mean±S.D.	Range
Leafy and fruity vegetables	1.6±2.7	0.07–7.30	4.2±4.3	1.00–17.3
Fruits	1.5±1.1	0.25–3.94	3.1±2.3	0.16–9.00
Meats and related items	3.8±3.8	0.40–12.1	25±13	2.87–43.5
Fish	2.25±0.99	1.00–3.33	19.9±3.6	15.5±23.5
Cereals/cereal products	2.37±0.64	1.53–3.07	16±14	3.54–33.4
Legumes	8.3±3.7	4.00–12.5	29±12	14.0–42.7
Tubers/tuber products	2.7±2.1	0.72–4.73	6.4±3.0	3.00–10.0
Spices/seasonings	4.7±4.1	0.40–13.3	22±23	0.20–56.9
Dairy products	0.91±0.31	0.60–1.27	19±12	6.37–35.6
Canned processed foods	1.29±0.50	0.87–2.00	8±11	0.33–23.5
Additives and sweeteners	1.00±0.94	0.33–2.40	13±17	0.06–36.9
Fats and oils	1.05±0.95	0.40–2.47	2.6±3.3	0.60–7.53
Confectioneries	1.04±0.77	0.60–1.93	3.4±3.3	0.27–6.87
Alcoholic beverages	0.15±0.13	0.06–0.24	0.21±0.09	0.18–0.23

Table 3
Comparison of Cu and Zn levels (mg/kg) in some Nigerian foods with levels in similar foods in other countries

Food	This study		Nigeria[a]		Sweden[b]		East Asia[c]		USA[d]		USA[e]	Egypt[f]
	Cu	Zn	Cu	Zn	Cu	Zn	Cu	Zn	Cu	Zn	Cu	Zn
Beef	0.89	49.0	–	–	1.60	23.5	1.60	22	7.24	81.7	0.58	10.5
Beans	6.87	42.7	1.3	0.75	5.6	27	8.8	11	2.72	14.0	3.08	29.1
Sugar	0.33	0.60	–	–	0.23	0.06	–	–	0.09	0.10	0.29	2.85
Potato	0.72	3.0	–	–	0.72	3.00	2.3	0.3	0.64	2.10	0.60	7.66
Pork	2.87	30.2	–	–	0.90	24	1.9	25	0.95	30.8	0.80	–
Corn	2.33	33.4	1.3	8.0	–		1.6	14	0.48	6.1	0.38	4.39
Yam	4.73	10.0	2.2	2.7	–		–	11	–	–	–	–
Rice	1.53	4.93	1.4	3.0	–		2.3	15	0.73	5.7	1.90	9.35
Bread	0.60	2.93	–	–	–		–	–	1.11	7.2	1.32	8.2
Egg	1.13	6.87	–	–	–		0.50	9.0	0.64	14.6	0.80	12.3

[a] Udoessien and Aremu (1991).
[b] Jorhem and Sundstroem (1993).
[c] Wu Leung and Butrum (1972).
[d] Pennington, Schoen, Salmon, Young, John and Mart (1995a,b).
[e] Lurie, Holden, Schuberf, Wolf and Miller-Ihli (1990).
[f] Hussein and Bruggeman (1997).

Table 4
Comparison of dietary intakes of Cu and Zn (mg/day) in this study with values for other countries

Country	Cu intake	Zn intake	Reference	Group
Asia	–	6–36	Bowen (1981)[a]	
Britain	1.51	9.05	Lewis and Buss (1988)	Elderly
Britain	1.25	8.9–9.3	Gibson (1985)	Children
Britain	1.5–3.1	9.1–14	Bowen (1981)	
Canada	2.2	11–20	Bowen (1981)	
Egypt	–	8.54	Hussein and Bruggeman (1997)	Adults
Europe (average)	–	6–40	Bowen (1981)	
Germany	2.7 (0.6–12.3)	12 (4.2–12.5)	Bowen (1981)	
Hungary	1.23	9.44	nagy (1987)	Adults
India	5.8	16	Bowen (1981)	
Japan	3.6	11	Bowen (1981)	
Java Island	1.7–2.5	–	Rivai, Suzuki, Koyama, Hyodo, Djuangsih and Soemarwoto (1988)	
Many Countries	3.5 (0.7–5.0)	13 (10–15)	Bowen (1981)	
Median (for all)	–	13	Bowen (1981)	
New Zealand	1.5–7.6	10	Guthrie and Robinson (1977)	Women
Nigeria	8.0	18.0	Udoessien and Aremu (1991)	Adults
Nigeria	–	7.3	Mbofung and Atinmo (1980)	Adults
Russia	1.3–4.3	9–16	Bowen (1981)	
Sweden	0.85–1.3	6–15	Bowen (1981)	
USA	–	8.11	Murphy, Willis and Watts (1975)	Adults
USA	–	10–15	Pennington and Gunderson (1987)	Adults
USA	0.76–1.7	11–18	Bowen (1981)	
Nigeria (this study)	2.64 (2.41–3.57)	15.8 (15.5–21.4)		
Recommended intake	2.5	15	WHO (1973, 1985); FAO (1985)	

[a] Literature summaries.

Results for the foods of Sweden, USA, Egypt and East Asia show high levels of these metals in beans, comparable to the levels found in this study. In many cases, the metal levels were higher in beans than in other foods.

The survey of the food consumption patterns clearly showed that the quality and quantity of foods consumed in an urban Nigerian city varied significantly according to the income class of the populace, because food is not very cheap in Nigeria, unlike in many developed countries. It was determined that different dietary intakes have to be estimated for three different classes: the high income, middle income, and low income groups. For example, the high and middle income group diets may contain a higher proportion of food items such as meats, fish, milk, ice-cream, beverages, which are considered as luxury among the lower income classes. Also, dietary consumption patterns were generally noted to be identical for both male and female adults. The calculation of the dietary intake incorporated data for non-alcoholic beverages and water which had been obtained from previous studies (Onianwa, Adetola et al., 1999; Onianwa, Ogunniyi & Ogunnowo, 1999). The daily dietary intakes for copper were estimated to be as follows: low income group, 2.41 mg/person/day; middle income group, 2.97 mg/person/day; high income group, 3.57 mg/person/day. Given an estimated population distribution ratio of 65:30:5 for the low:middle:high income groups, the weighted average intake for the populace was estimated to be 2.64 mg Cu/person/day. The higher level of intake in the middle and high income classes can be explained by the wider variety of food types eaten by these groups, and the relatively higher contents of Cu in such foods. Given the recommended daily allowance for dietary copper which is 2.5 mg/day (Food and Agriculture Organization [FAO], 1985; WHO, 1973, 1985; National Research Council: Food and Nutrition Board, 1989), it may thus be estimated that about 65% of the Nigerian adult population, who are of the low income group, have copper intakes which are slightly below the recommended daily allowance. The estimated average intake of 2.64 mg/day obtained in this study compares well with the recommended values and is compared with dietary intake values for Cu in other countries in Table 4. The estimate of 2.64 mg Cu/day from this study is far lower than the 8.0 mg/day obtained from the previous Nigerian study of Udoessien and Aremu (1991) in which only a much limited number of staple food items were assessed, but falls within the general range of values reported for other countries in Table 4. Bowen (1981) has calculated an average of 1.6–3.4 mg/day for many countries. The dietary Cu intake estimates for USA, Britain, Hungary and Canada (ranging from 0.7 to 1.7 mg/day) are slightly lower than the Nigerian value.

Dietary zinc intake was estimated from this study to be as follows: low income group, 15.5 mg/day; middle income group, 15.8 mg/day; and high income group, 21.4 mg/day. In this case, the intake by the high income group is higher than those of the other groups. The weighted average for the entire population was calculated to be 15.8 mg Zn/day. This average well satisfies the recommended daily allowance of 15 mg Zn/day, and is reasonably close to 18.0 mg/day obtained for Nigeria by Udoessien and Aremu (1991). However, the sufficiency of this level of dietary intake cannot be properly determined without a knowledge of the phytic acid contents of the food items. This is because high phytic acid contents in foods (particularly those of vegetable origin) inhibit the availability of dietary zinc (O'Dell, Boland & Koirtyohann, 1972; Bindra, Gibson & Thompson, 1986; Ellis, Kelsay, Reynolds, Morris, Moser & Frazier, 1987). Table 4 also lists zinc dietary intake values for other countries. The values in most countries appear to be generally lower than the recommended limit of 15 mg/day and are thus lower than the Nigerian value. However, some countries, such as USA (Pennington & Gunderson, 1987), Russia, all Europe, all Asia (Bowen, 1981), have reported levels for some of their studies which are about the same or even higher than the Nigerian value.

The results generally indicate that the levels of zinc and copper in most Nigerian foods compare favourably with those in similar food items from other parts of the world. Also, foods such as meats, fish, milk, which are eaten more by the high income and the middle income groups contribute more to the total dietary intakes of copper and zinc. The estimates of the average dietary intakes for both metals meet the recommended allowances, and fall within the range of intake values obtained for many other countries.

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