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The elemental analysis of staple foods for children in Tanzania as a step to the improvement of their nutrition and health

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A B S T R A C T

The objective of this study was to evaluate the contents of essential elements in the two staple foods (rice and maize flour) consumed by children in Tanzania as a possible selection measure for high nutrient foods in order to combat malnutrition. Samples were analysed using proton-induced X-ray emission (PIXE) at the University of Surrey Ion Beam Centre. The mean concentrations of elements determined in the two staple foods are presented and compared with the mean concentrations published in the literature.

1. Introduction

Trace element malnutrition is reported to be the biggest cause of death for children in developing countries. It is said to contribute to 53% of death related to infectious diseases in children of age under 5 yr (WHO, 2005). This is because deficiency of trace elements impairs the immunity system of a body and makes the body more susceptible to communicable diseases. Malnutrition normally occurs when the essential elements are not sufficient to fulfil the need of the body to develop and function normally. This may result from poor access to nutritious food, a decreased bioavailability of the elements in food, excessive loss due to infectious diseases or a combination of these factors. Iron (Fe) and zinc (Zn) deficiency are the nutritional deficiencies which mostly occur in the countries which depend on cereals as their staple foods. This is because these foods contain phytates, which bind Fe and Zn to form insoluble salts thus hindering their absorption in the gastrointestinal tract.

The statistics of malnutrition in Tanzania are also high, especially among children of age below 5 yr. Of all, 43.8% of the children under 5 are reported to be stunted, which indicates chronic malnutrition among this age group (WHO, 2005). Studies have also shown persistent iron-deficiency anaemia and common stunted growth among school children (Lwambo et al., 2000; Stoltzfus et al., 2001). The severity of malnutrition to these children is further aggravated by the prevalence of parasitic infections such as hookworms and malaria, which increase the morbidity and mortality rates in children.

Studies of essential elements in food and diets are fundamental to the reduction of malnutrition, improvement of human welfare and resistance to disease. Results from these studies will provide information that can verify the nature of the nutrition problem within a society and the effectiveness of the specific solution or intervention. In this study samples of two staple foods (rice and maize flour) which were locally cultivated in different regions and are consumed by children in Tanzania were analysed to determine the levels of essential trace elements. Concentration levels of phosphorus (P) which are a determinant of the anti-nutrient compound phytate were also found and correlated with concentrations of Fe and Zn in both foods. One of the aims of the project is to identify maize and rice varieties with low concentrations of phytates.

2. Methodology

Seventy-one samples of rice and 56 samples of maize flour which are the main staple foods for children were collected in four regions of Tanzania. The samples were ground into fine powder (size $<$ 0.074 mm) using a mortar and pestle and then mixed with a polyethylene spatula washed with double distilled deionised water, before a subsamples of ~60 mg were compressed into pellets of diameter 5 mm to give reproducible irradiation and counting geometry. The samples were stuck on 3 mm thick aluminium plates using double-sided adhesive tape and were carbon coated by vacuum carbon evaporation and then graphite was tagged on each side of the pellets to ensure good passage of charge. Sixteen samples were placed onto a plate together with 2 standard reference materials from National Institute of Standards and Technology (NIST); peach leaves (SRM 1457) and pine needles (SRM1575a) for quality assurance. The samples were irradiated

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using a proton beam of size $3 \times 4\,\mu m^2$, current ~200 pA and energy 2.5 MeV for 10 min scanning an area of $1.5 \times 1.5\,mm^2$ of the pellets. The characteristic X-ray spectra were collected by an $80\,mm^2$ Si(Li) detector of resolution 160 at 5.9 keV (with a Be filter of thickness 130 μm) placed at 135° to the beam and 25 cm from the samples. The RBS spectra were collected using a Si(Li) detector placed at 160° and 30 mm from the samples. Net areas from GUPIX of Dan32 package were used to calculate the concentrations of elements in the samples using a comparative method (Maxwell et al., 1995). A sample of peach leaves from each plate was used as the comparator for the samples on the same plate to ensure that the same analytical conditions prevailed.

3. Results and discussion

A statistical summary of data in μg/g is presented in Tables 1 and 2 for rice and maize flour, respectively, showing the arithmetic mean (±standard error of the mean), geometric mean (×/÷standard deviation), and median for 8 elements in the two staple foods. Whenever the concentration of an element was below the detection limit of the method, a mean value equal to one-half of the detection limit was used in the statistical analysis instead of missing data.

A *t*-test carried out to calculate the statistical differences between the mean concentrations of the elements found in the two foods revealed that rice cultivated in Tanzania had significantly ($p < 0.01$) higher concentrations of P, Mn, Cu and Zn than maize flour. Moreover, rice was found to have higher concentrations of Fe and Ca than maize flour although the differences were not significant (see Tables 1 and 2). The lower elemental contents of maize flour than rice might also be contributed to milling of the maize as this process includes the removal of seed germ and the outer layer of the maize grain. As with all cereals, most nutrients are concentrated in the outer layer of the grain; thus removing these layers in the milling process might result in a big loss of minerals. Bauernfeind (1991) reported a loss of 79% of Zn, 74% loss of P, 54% of Fe and 53% of Ca when maize grain was milled Maina (2005) reported a 70% loss of Zn, 34% Fe and 13% Ca. However, the percentage loss of these elements will depend on the degree of refining of the maize flour.

The nutritional value of any diet depends also on the bioavailability of the elements within the food. The main determinant of the bioavailability of elements (Fe and Zn) in the stomach is phytic acid, which in this study was determined by the concentrations of P in the food. Since the mean concentration of P was found to be 2 times higher in rice than in maize flour, lower concentrations of Fe and Zn in maize flour would be compensated by their higher bioavailability in the stomach.

Most of the elements found in rice samples analysed in this work are lower than the concentrations of the elements reported in the unpolished rice from Taiwan (Yeh et al., 1976). This might also indicate the influence of polishing on content of elements in rice. However, Zn and Cr were higher in this study whilst Fe had a similar mean concentration with the reported rice from Taiwan. The mean concentration of Zn, although higher in the unpolished rice from Taiwan, was found to be slightly (12%) lower than the value reported in rice from Nigeria (Chukwuma, 1995). The mean concentration of Fe and Zn were within the range of approximate composition of milled rice reported by FAO (FAO, 1993). Ca in this study was less than the extreme lower value and P was higher than the extreme upper value of the range reported in rice by FAO (FAO, 1993). However, P of mean concentrations from 2550 to 3290 μg/g has been reported in rice from different locations in Arkansas, USA (Slaton et al., 2002).

The mean concentrations of K, Ca, Mn, Fe, Cu and Zn obtained in maize flour analysed in this study were found to be comparable to the elemental concentrations of these elements reported in different brands of processed maize flour in Kenya (Maina, 2005). Moreover, the Fe content in the samples were similar to the mean concentration of Fe reported in maize flour in Zimbabwe (20.6 μg/g), while the Zn mean concentration was about 57% lower than the Zn concentration in maize flour in Zimbabwe (Long et al., 2004).

The chemical composition of rice grain and maize flour may vary depending on the genetic factor of their varieties, on the environmental conditions as well as on post-harvest operations such as degree of milling and conditions of storage. Yet rice grown in the three regions of Tanzania and maize flour milled from maize grains cultivated within the country have the elemental contents in the range reported elsewhere (Maina, 2005; Long et al., 2004; Slaton et al., 2002).

The concentrations of P in both staple foods were high in general. This observation indicates that the concentration of the anti-nutrient compound phytic acid in these foods is also high. High concentration of phytic acid implies low absorption of Fe and Zn in the gastrointestinal tract, which might lead to trace element malnutrition in children.

The absorption of Fe and Zn could be boosted up if a meal is taken with a portion of animal protein because these proteins prevent the elements from forming the insoluble phytates with the phytic acid in the foods. However, most of the Tanzanian population especially those living in the rural areas cannot afford to eat meat. Instead they normally have their meals with a relish of green vegetables or beans. Meat is reported not to be in the table of the most frequent foods consumed by the rural population whilst its intake is about 5.6% for the urban people (Mazengo et al., 1997). The green vegetables and beans lower the bioavailability of the essential elements further as they also

Table 1
The overall elemental concentrations (μg/g) in rice ($n = 71$) collected in three regions of Tanzania; arithmetic means (A. Mean), geometric means (G. Mean) and median are presented

Elements	A. Mean	G. Mean	Median
P	2976±84	2890×/÷706	2874
Cl	400±19	374×/÷160	360
K	1755±54	1707×/÷452	1646
Ca	127±6	118×/÷49	119
Mn	21±1	20×/÷8	19
Fe	25±2	21×/÷18	19
Cu	4±0.5	3×/÷4	3
Zn	29±1	28×/÷9	28

Table 2
The overall elemental concentrations (μg/g) in maize flour collected in two regions of Tanzania ($n = 56$); arithmetic means (A. Mean), Geometric means (G. Mean) and Median are presented

Elements	A. Mean	G. Mean	Median
P	1506±85	1386×/÷633	1453
Cl	491±15	440×/÷114	504
K	1776±71	1698×/÷529	1699
Ca	77±3	73×/÷25	76
Mn	3±0.2	2×/÷1	2
Fe	20±2	17×/÷13	18
Cu	2±0.2	1×/÷2	1
Zn	10±1	9×/÷5	9