ESSENTIAL TRACE METALS IN SELECTED MAIZE FLOUR BRANDS CONSUMED IN NAIROBI, KENYA: APPLICATION OF TXRF

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Abstract – Human beings obtain their essential trace metals form their diets. The objective of this study was to determine the Mn, Fe, Cu, and Zn concentration levels in maize flour and based on the results estimate the daily intake of these essential metals through consumption of Ugali; a thick porridge made from maize flour. Maize flour was bought from various supermarkets in the City of Nairobi. The samples were microwave digested and the metals concentrations determined using a S2-Picofox TXRF spectrometer. Copper and Mn concentrations ($\mu g\ g^{-1}$) in the samples were low with Mn values ranging from 1.9 to 10.9 while Cu concentrations ranged from 1.1 to 7.9. On the hand the Fe and Zn concentrations ($\mu g\ g^{-1}$) were high ranging from 20.3 to 148 and 19.3 73.2 respectively. The consumption of ugali provides adequate daily intake for Fe but is very poor in meeting daily intakes for Mm, Cu, and Zn. Further studies should be done to determine the bioavailability of these metals in ugali.

Keywords: essential trace metals, TXRF, estimated daily intake, human health, maize flour.

1. INTRODUCTION

Essential trace metals are important in human health because they bind to proteins to form metalloproteins which are involved in various biochemical and physiological functions. A metal in the metalloproteins may be part of enzymatic action, have a structural and storage function or be transported to its target site by the protein [1]. Most, but not all trace elements act primarily as catalysts in enzymic systems [2]. Currently, Cr, Mn, Fe, Co, Ni, Cu, Zn, Se, Mo are regarded as essential [3]. Human beings obtain their trace metals needs from their diets and it is therefore important to determine the level the adequacy of these diets in terms of trace metal content.

Many studies have been done on the content of essential trace metals in a variety of diets with an emphasis on nutritive level. In a study of a large variety of French foods by Leblanc et al [4], concentration values of 18 elements were reported and the authors concluded that the diet was nutritionally safe. In a similar study on Indian diets, Singh and Garg [5] reported presence of essential metals in cereals (flour form), vegetables, spices and condiments. Rice and wheat, being the two foodstuffs that are consumed by many people globally, have been widely studied. In their study on rice consumed in Nigeria, Adedire et al [6] found that the concentration levels of the essential metals were safe to consumers. However, Ahmed et al [7] observed that the concentrations of essential trace metals in both rice and wheat consumed in Bangladesh may pose a health risk to the consumers.

Globally, maize is the third staple food after wheat and rice and it may be consumed in processed or unprocessed form [8]. In Kenya, it is the main carbohydrate food and it is consumed mainly in its flour form where over 88% of households consume it at least 55 % in a week [9]. The main form in which it is consumed is a thick porridge (Ugali). Since it is such an important staple food in Kenya, it is important to determine its nutritive value. The objective of this study was to determine the concentrations of Mn, Fe, Cu and Zn in maize four and estimate the dietary intake of these metals.

2. MATERIALS AND METHODS

2.1 Sampling

A total of 43 sifted maize flour samples and were obtained from Five (5) major supermarkets in Nairobi's Central Business District. The samples were of 9 different brands and packaged by different companies. To avoid mentioning names of companies, the samples were labelled A1 to A9.

2.2 Sample preparation for TXRF analysis

Three sub-samples of approximately 0.30 to 0.35g of each maize flour sample were measured into clean digestion vessels and 10 mL of concentrated nitric acid (analar grade) was added and the sample digested using a microwave digester for 30 minutes at a maximum temperature of 180 ^{o}C.

Each digest was transferred to a 50 mL cylinder and topped to 50 mL with double distilled water. From each sample solution a sub-sample of 20 mL was measured and put into a clean vial and 10µL of a 1000 ppm Gallium stock solution (as internal standard) resulting in a concentration of 0.5 ppm Ga in each sample.

The samples were homogenized/mixed using a vortex mixer for one minute each. Aliquots of 10 µL of each sample were pipetted onto a clean quartz carrier using a micro-pipette and the carriers dried in an oven at 60 ^{o}C.

2.3 Sample spectrum de-convolution and quantitative analysis

Each sample carrier was irradiated for 1000 seconds using a Molybdenum tube S2-PICOFOX TXRF Spectrometer operated at 50 kV and a current of 1 mA. The evaluation of spectra for concentration values was done using S2 PICOFOX software on the basis of the chosen elements. Concentrations were calculated based on the net intensities of the analyte peak elements and that of the internal standard as per equation 1.

$$C_x = \frac{Nx / Sx}{Nis / Sis} x Cis \qquad (1)$$

where C_x is concentration of the analyte, C_{is} is the concentration of the internal standard, N_x is the net intensity of the analyte, N_{is} is net intensity of the internal standard, S_x is the relative sensitivity of analyte and S_{is} is the relative sensitivity of internal standard.

2.4 Estimated daily intake

The estimated daily intake (EDI) of the essential trace metals through the consumption of ugali were calculated using the following formula [6]:

$$EDI = C_m \, x \, M_g \qquad (2)$$

where C_m is the daily consumption of ugali (g) M_g is the mean concentration of the essential trace metal in maize flour. The daily consumption of ugali was estimated by buying ugali portions from seven (7) typical restaurants, weighed the portions and obtained the average.

Samples of 3 g were sampled from each of the ugali portions and oven dried at 60 ^{o}C for 9 hours and the average moisture content was found to be 70.1%. This value was used to estimate the daily consumption of ugali.

3.0 RESULTS AND DISCUSSION

3.1. Essential metal concentrations

The concentrations of the essential trace metals are in two clusters (Table 1). The first cluster has Mn and Cu and it is characterized by low concentrations with Mn concentrations being slightly higher. The second cluster is formed by Fe and Zn and characterized by high concentrations with the Fe concentrations being slightly higher than those of Zn. In addition, the concentrations of Mn and Fe vary in the same pattern where samples A2, A4, A7 and A9 are high compared to the rest (Figures 1 and 2). The variation of Cu and Zn in the samples follows almost a similar pattern, in particular from samples A4 to A9 (Figures 1 and 2). Almost three decades ago, Korir [10] carried out a similar study where metal concentrations (µg g^{-1}) in local maize flour samples were found to vary as: Mn, 1.9 – 3.3; Fe, 19 – 39; Cu, 0.9 – 1.2; and Zn, 7.0 – 13.0. A comparison with this study shows that the current maize flour samples have higher metal concentrations. The main reason could be attributed to the concerted effort by the government to fortify the main staple foods with essential elements.

In addition, the increased usage of farm inputs that contain high metal concentrations is also another factor that may have increased essential metals in maize flour samples. Another possible source of metals could from the machines used for milling the maize seeds.

The results of this study are similar to those obtained by Singh and Garg [6] in their study on Indian foods where their maize flour data was Mn (3.35 μg g^{-1}), Fe (46.6 μg g^{-1}) and Zn (14.5 μg g^{-1}). A similar trend is reported by Gwitz and Garcia-Casal [9] with Mn (5 μg g^{-1}), Fe (24 μg g^{-1}), Cu (2 μg g^{-1}) and Zn (17 μg g^{-1}). Their results on Fe and Zn are lower than the ones obtained in this study and this may be attributed to different soil conditions.

3.1. Estimated daily intake

The estimated daily intake (EDI) for Mn and Cu are in the same range (Table 2) and almost three times below the tolerable levels [11]. On the other hand, the EDI for Fe is almost within the range of the tolerable levels. However, the Zn EDI is far below the tolerable daily intake. These results show that if ugali was the only food consumed, it would not provide adequate nutritional value for Mn, Cu and Zn. A comparison with EDI results for rice which is the second most consumed food, the values reported by Edadire et al [6] – Mn (0.60 μg g^{-1}), Cu (0.21 μg g^{-1}) and Zn (0.72 μg g^{-1}) are lower than our data whereas the results reported by Ahmed et al [8] – Mn (1.94 μg g^{-1}), Cu (0.83 μg g^{-1}) and Zn (5.48 μg g^{-1}) are similar to those reported in this study.

4. CONCLUSIONS

Ugali, a common dish in Kenya is adequate in providing Fe nutrition but inadequate in Mn, Cu and Zn nutritional levels. The bioavailable levels of these metals in ugali should be studied to confirm the nutritional data obtained in this study

REFERENCES

[1] C. G. Fraga, “Relevance, essentiality and toxicity of trace elements in human health” *Molecular Aspects of Medicine*, vol 26 pp. 235 – 244, 2005.

[2] M. O. Oliver, “Soil and human: a review”, *European Journal of Soil Science*, vol 48, pp. 573 – 592, Decemnber 1997.

[3] P. B. Tchounwou, C. G. Yedjou, A. K. Patlolla, and D. J. Sutton, ”Heavy Metals Toxicity and the Environment”, *EXS*, vol 101, pp 133 – 164, 2012.

[4] J. C. Leblanc , T. Guérin , L. N., G. Calamassi-Tran , J. L. Volatier and P. Verger, “Dietary exposure estimates of 18 elements from the 1st French Total Diet Study”, Food Additives and Contaminants, vol 22, no 7, pp 624 – 641, July 2005.

5] V. Singh, A. N. Garg, “Availability of essential trace elements in Indian cereals, vegetables and spices using INAA and the contribution of spices to daily dietary intake”, *Food Chemistry*, vol 94, pp. 81–89, 2006.

[6] C. O. Adedire, J. A. Adeyemi, A. C. Paulelli, A. C. Martins-Junior, K. D. Ileke, F. R. Segura, V. C. de Oliveira-Souza, B. L. Batista and F. Barbosa Jr, “Toxic and essential elements in Nigerian rice and estimation of dietary intake through rice consumption”, *Food Additives & Contaminants: Part B*, vol. 8, no. 4, pp. 271–276, 2015.

[7] Md. K. Ahmed, N. Shaheen, Md. S. Islam, Md. H. Al-Mamun, S. Islam and C. P. Banu, “Trace elements in two staple cereals (rice and wheat) and associated health risk implications in Bangladesh”, *Environ Monit Assess*, vol. 187 pp. 326, 2015.

[8] J. A. Gwirtz and M. N. Garcia-Casal, “Processing maize flour and corn meal food products”, *Ann. N. Y. Acad. Sci.*, vol. 1312, pp. 66 – 75, 2014.

[9] T. Olielo, “Food security problems in various income groups of Kenya” AJFAND, vol. 13 no. 4, pp. 1-10, 2013.

[10] K. Korir, ‘Trace element analysis of environmental and biological samples using total reflection X-ray fluorescence (TXRF), *MSc thesis, University of Nairobi*, 1998

[11] V. M. J. Gibney, H. H. Voster and F. J. Kok (eds) *Introduction to human nutrition* Blackwell Publishing, 2002.

Table 1 Concentration of Mn, Fe, Cu and Zn in Maize Flour Samples (μg g^{-1} ± 1SD)

Sample	**Mn**		**Fe**		**Cu**		**Zn**	
	Mean	Range	Mean	Range	Mean	Range	Mean	Range
A1	3.5 ± 0.6	3.0 – 4.2	37.0 ± 10.6	25.0 – 45.2	2.7 ± 0.7	2.2 – 3.5	36.0 ± 18.4	24.9 57.2
A2	3.9 ± 1.2	2.9 – 5.6	47. 4 ± 2.8	45.0 – 51.1	3.6 ± 2.9	1.7 – 7.9	28.4 ± 3.1	24.8 – 31.8
A3	2.8 ± 0.9	1. 9 – 4.1	35.6 ± 12.5	23.8 – 54.7	2.9 ± 1.8	1.1 – 5.4	39.3 ± 11.1	26.5 – 49.0
A4	5.5 ± 4.7	2.5 – 10.9	79.5 ± 61.7	27.9 - 148	3.7 ± 3.0	1.9 – 7.1	38.6 ± 30.0	20.6 – 73.2
A5	3.4 ± 1.1	2.6 – 4.8	46.4 ± 25.9	24.5 – 81.5	3.3 ± 0.9	2.1 – 4.2	33.6 ± 3.5	30.1 – 37.4
A6	2.8 ± 0.7	2.1 – 3.6	26.2 ± 4.7	20.3 – 31.3	2.4 ± 1.0	1.4 – 3.8	21.7 ± 2.0	19.3 – 24.3
A7	4.5 ± 2.6	3.2 – 5.6	53.8 ± 25.4	33.8 – 87.2	2.1 ± 0.3	1.7 – 2.3	25.6 ± 4.9	20.1 – 31.8
A8	2.8 ± 0.1	2.7 – 2.8	27.2 ± 4.7	23.9 – 30.6	2.3 ± 0.2	2.2 – 2.4	23.9 ± 9.7	17.0 – 30.7
A9	3.7 ± 0.5	3.4 – 4.1	47.8 ± 14	37.6 – 58.0	2.5 ± 0.4	2.3 – 2.8	29.3 ± 0.3	28.9 – 29.7

Table 2 Estimated daily intake (EDI) of essential trace metals compared to tolerable daily intake (mg day^{-1})

Element	**EDI (Range) mg day^{-1}**	**Tolerable daily intake (mg day^{-1}**
Mn	0.5 – 0.9	2.3
Fe	4.5 – 13.6	8.0
Cu	0.4 – 0.6	1.5
Zn	3.7 – 6.7	40

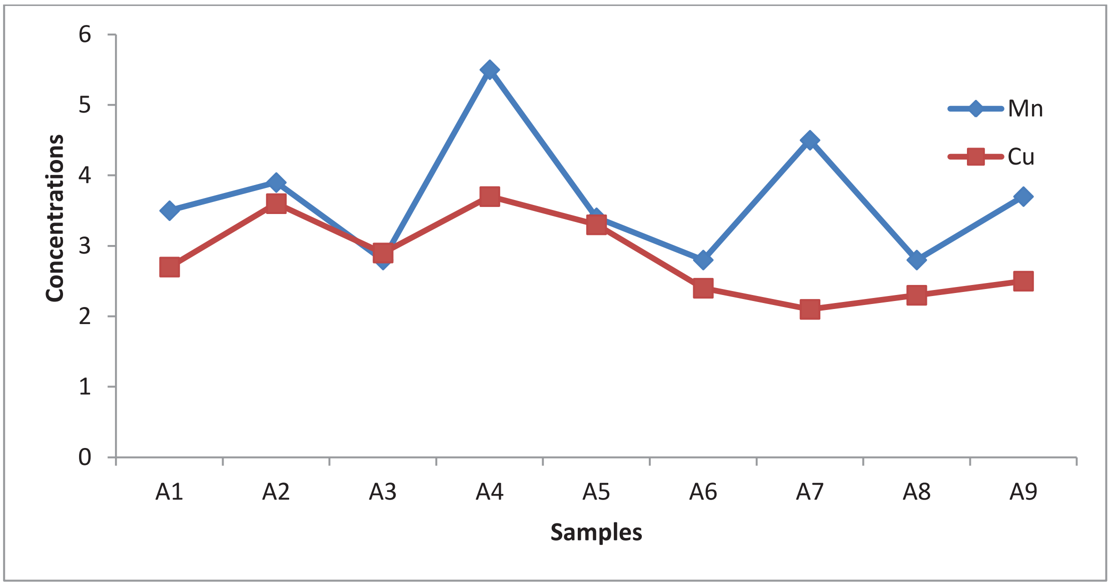

Figure 1: Mn and Cu concentrations in the flour samples (µg g^{-1})

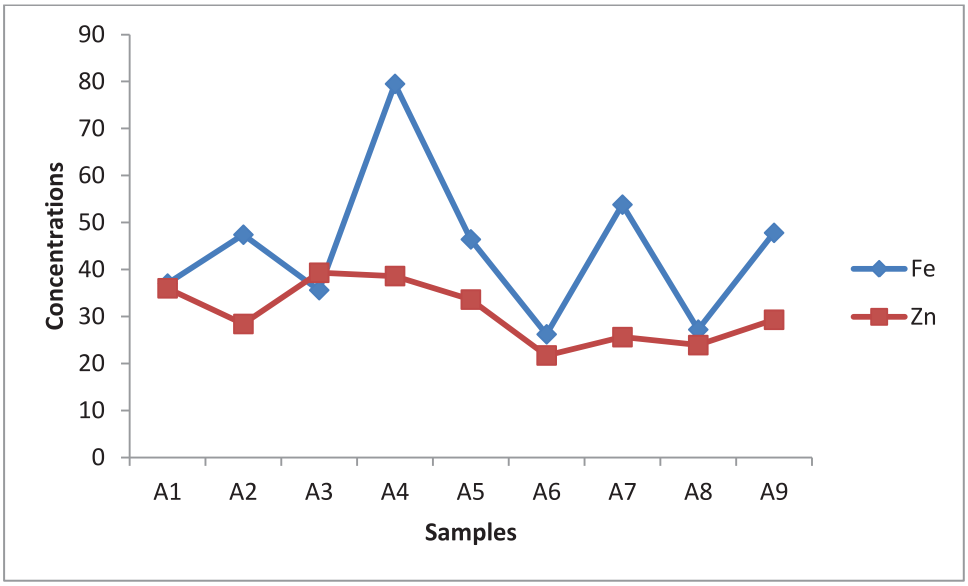

Figure 2: Fe and Zn concentrations in the flour samples (µg g^{-1})